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ANNALS of SURGERY

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ANNALS OF SURGERY

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REPARATIVE SURGERY OF COMPOUND BATTLE FRACTURES IN THE MEDITERRANEAN THEATER OF OPERATIONS

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EXTREMITY SURGERY of the war wounded is divided into three phases[1]:

1. *Initial:* The primary excisional surgery performed in Army Field and Evacuation Hospitals as soon after wounding as possible (usually 8–24 hours) directed at the saving of life and limb and the prevention of infection.

2. *Reparative:* Performed in fixed hospitals at the Base directed at wound healing, anatomic and functional restoration of the extremity and rehabilitation or safe transport to the Zone of Interior in a lag-period of treatment after all that is necessary in the overseas Theater to minimize permanent disability has been achieved.

3. *Reconstructive:* Performed in the hospitals of the Zone of Interior directed at correction of residual defects and deformities resulting from the war wound.

Reparative surgery is largely dependent upon adequate initial surgery,[2] including bold incision, excision of dead and devitalized tissue, good drainage of the wound depths and dead space, an occlusive dressing, and adequate immobilization. It is facilitated by a short line of evacuation which permits transferring of the patient within a few days after wounding to a Base Hospital that is functioning close behind the combat zone. When these conditions are ideally fulfilled, surgical repair of open wounds is a logical and successful procedure in wound management. If the initial surgery has been inadequate, additional excisional surgery anticipating staged repair is usually necessary to prevent or cut short wound sepsis. Successful reparative surgery may make reconstructive surgery unnecessary or may return the patient to the Zone of Interior in a condition that will permit earlier and complete reconstructive surgery with enhanced chances of success.

CONCEPT OF REPARATIVE SURGERY

Since the early days of this Theater in North Africa, repeated observation has established that wounds with obviously retained devitalized tissue became septic and drained pus profusely. Large hematomata in undrained dead space often decomposed into pus. Systemic or local chemotherapy, or their combination, did not prevent wound sepsis in the presence of dead tissue. Once wound sepsis had developed, there was continuing local

necrosis of living tissue and a vicious circle was established. Large granulating areas exuding plasma were observed to develop and harbor surface infection. These septic wounds, however, seldom manifested the cardinal signs of inflammation. Conversely, wounds which were free of devitalized tissue on their admission to Base Hospitals were clean grossly and free of sepsis. As healing by granulation occurred, many developed surface infection.

Following these observations, reparative surgery began with the successful secondary closure of clinically clean soft-part wounds, even though cultures taken preoperatively demonstrated the presence of an aerobic and anerobic bacterial flora.[1, 3, 4, 5] A wound free of devitalized tissue sutured at its primary dressing, four or five days after initial surgery, without dead space, hematoma in the depths, or excessive tension, and supported by a good pressure dressing and adequate splinting healed regardless of the bacterial flora. Successful suture depended upon a proper clinical appraisal of the wound, atraumatic technic, and surgical limitations imposed by the character of the defect. The clinical observations supported by the bacteriologic studies of Lyons and Rustigian[3] on war wounds which demonstrated that clean wounds and wounds with established sepsis may have comparable bacterial flora, have led to the following concept:

Wound sepsis becomes established as a result of the septic decomposition of devitalized tissue, including hematoma in dead space, rather than from the action of bacteria on living tissue. The devitalized tissue serves as a pabulum[3] for wound pathogens. If the pabulum is not present and is not created by surgery, and if living tissue is protected from invasive infection by an effective antibacterial agent, the bacterial flora of an open wound may be disregarded, wound sepsis need not be feared, and any indicated reparative procedure may be performed under established surgical principles with the anticipation of good wound healing.

Battle-incurred compound fractures demand special considerations when compared with those resulting from traffic and other accidents. Battle fractures are always compounded from "without-in" by missiles which have passed through clothing, often soaked with the grime and mud of the battlefield. The great majority are caused by high explosive shell fragments resulting in extensive muscle and bone damage. Clothing, wood, metallic foreign bodies, cement and mud are frequently buried in the depths of the wound far removed from their point of entry. In spite of excellent field service in this Theater for evacuation of the wounded from the battlefield to a hospital equipped for surgery, the time-interval between wounding and initial surgery usually exceeds 12 and often 24 hours. Accordingly, the wounds are not merely contaminated but are heavily infected with bacteria. The fractures are usually severely comminuted, often with bone loss. These injuries require long incisions, often multiple, for adequate exposure of the devitalized tissue and foreign material and to permit adequate excisional surgery. The large, often irregular, or multiple wounds made by surgeon

and missile must remain unsutured following initial surgery. They, together with muscle and bone loss incident to the injury and the surgery, present a picture and a problem peculiar to military surgery.

Reparative surgery recognizes that complete excision of the devitalized tissue in compound battle fractures is usually impossible or impracticable. At initial surgery, completely detached bone fragments are deemed to be avascular tissue and potential sequestra and, therefore, they are removed together with the devitalized soft tissue. Fragments with complete or partial periosteal attachment are preserved projected towards union of the fracture. Muscle, fascia, tendon, and periosteum attached to the fragments and the denuded cortex of bone constitute questionable devitalized tissue which probably remains in every fracture. Blood clot may form in an undrained area particularly in the dead space of the unreduced fracture or the defect created by the necessary muscle excision. The wounds of these injuries which have had adequate initial surgery have been observed in many instances to be draining profusely on admission to the Base Hospital. Unless wound sepsis became established, the profuse drainage ceased after several days. The discharge has been attributed to the spontaneous sequestration of the residuum of devitalized tissue and has been termed "the products of injury necrosis."[16] However, it is recognized that the residual devitalized soft tissue, partially denuded fragments, or dead space with a contaminated blood clot may be a nidus of infection with wound pathogens,[3] leading to abscess formation with continuing necrosis of living tissue within the wound. These are some of the factors that create specialized problems in the reparative management of compound fractures.

Every method of treating compound fractures seeks to obtain bony union with minimum deformity, a healed wound and maximum function of the extremity. During the year 1943 and early 1944, in the North African Theater of Operations, compound battle fractures were treated by a modified Orr method,[6] consisting of an open wound, infrequent occlusive dressings and traction or plaster immobilization. Wound healing by granulation and the resultant scar formation were accepted as necessary undesirables. In certain instances poor fracture results, malunions, or inevitable nonunions were accepted rather than risk "a stirring-up" of the wound by an open reduction. Wound sepsis with continuing local necrosis of living tissues became established in many cases, particularly in the exposed fracture sites of subcutaneous bones. Wounds with gross retained dead tissue were often managed by a "hands-off" policy which anticipated the spontaneous sequestration of the dead tissue rather than a delayed surgical excision. The unreduced fracture which called for repeated manipulations or adjustments of position in traction was particularly vulnerable to sepsis. A proper appraisal of the problem demonstrated the need for improvement which could be achieved only by a changing approach.

With a background of a year's experience, study and observation in the Theater of Operations, reparative surgery of compound fractures was

visualized and partially planned during the late months of 1943. Following in the wake of successful reparative management of soft-part wounds, it was initiated during the first quarter of 1944, catalyzed by the availability of penicillin therapy.* During the memorable days of Cassino and Anzio, it developed into a plan of management based upon continuing pooled experiences of the Theater surgeons.

In this Theater certain previously planned favorable operations factors obtained:

1. Experienced Forward Hospitals with standardized principles of excisional surgery and transportation splinting.
2. Short chain of evacuation, ambulance and train (Cassino), and air evacuation (Anzio) from Forward to Base Hospital predisposing to safe early transfer of the wounded.
3. Experienced Base Hospitals functioning close behind the combat zone.
4. A bed status in the Base that permitted the patients to be held for reparative surgery and rehabilitation or transfer to the Zone of Interior.
5. An Army blood bank supplying low titer-o blood to and augmenting that drawn in Forward Hospitals and unit banks in each Base Hospital supplying type specific blood.

Such was the prologue for reparative surgery of compound fractures at the "Fall of Rome."

The reparative surgical program for compound fractures has as its objectives: 1. Minimum wound sepsis. 2. Improved fracture reduction and stabilization. 3. More rapid wound healing, with minimum scar formation. 4. Maximum functional restoration of the extremity.

These objectives are approached by a plan of management based upon: (a) Blood replacement. (b) Chemotherapy. (c) Surgery. Good surgery is the keystone of the program, with blood replacement and chemotherapy as adjuncts.

BLOOD REPLACEMENT

In spite of what is considered to be an adequate use of blood replacement therapy in the forward area to combat shock, traumatic and operative, patients with compound fractures of the long bones have consistently shown anemia on admission to the Base. Tables I and II show the hematocrit readings obtained in two groups of battle casualties on admission to Orthopedic Sections of two General Hospitals. The tables are separated to allow column 4 of Table I to be presented as evidence of the blood loss sustained by a patient with a battle-incurred fracture of the femur. It will be noted that 50 per cent of this group had hematocrits under 30.

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* The counsel and active participation of Major Champ Lyons, M.C., of the staff of Surgical Consultant, M.A.T.O.U.S.A., was invaluable in the development of the program.

TABLE I(7)

Hematocrit	No. Cases	Percentage	No. Cases of F.C.C. Femur
Under 30	33	24%	19
31–35	24	17%	9
36–40	56	40%	8
Over 40	25	18%	2
	138	100%	38

TABLE II(8)

Hematocrit	No. Cases	Percentage
Under 30	37	22%
30–36	44	26%
37–42	54	32%
Over 42	31	19%
	166	100%

In order to correct the secondary anemia, type-specific cross-matched whole blood is given preoperatively in an effort to obtain an hematocrit reading of 40, or better, in all compound fractures on which any major reparative procedure is contemplated. Preoperative blood requirements are calculated on the basis of 500 cc. for each three to four points deficit of the hematocrit. There is no proof that this therapy is necessary but it is accepted *a priori* that the wounded man with an hematocrit of 40 is in better condition to withstand a long anesthesia and operative procedure than if his anemia is uncorrected. Additional blood to compensate for operative loss is frequently given during the operation and postoperatively if anemia is reëstablished. Repeated observations by many surgeons that the patients tolerated well and "looked good" after the surgery is sufficient to justify this use of blood replacement therapy. It has not been possible to compile confirmatory evidence, but blood therapy is believed to aid in the prevention of chronic sepsis, and in wound healing.

CHEMOTHERAPY

Penicillin has been accepted as the most powerful available antibacterial agent to which the bacterial flora, aerobe and anerobe, of war wounds have been proven sensitive. It is recognized that penicillin will protect *living* tissue against invasive infection but it is also recognized that penicillin will not sterilize dead, devitalized or avascular tissue which, inadvisably or of necessity, remains in the wound, nor will it prevent the septic decomposition of a contaminated blood clot which collects in unobliterated or undrained dead space or neutralize locally necrotizing enzymes in undrained pus.[9, 10] Therefore, penicillin is used for the protection of the living tissue from the invasive action of bacteria accepted as present in the residuum of devitalized tissue remaining in compound fractures. The agent will not sterilize that residuum, therefore, surgical measures are necessary for its management. Therapy is continued until wound surgery has been completed, wound healing has been sufficiently obtained and the residuum of devitalized tissue has sequestrated and drained off or has absorbed. Penicillin therapy is used to provide an increased margin of safety in the performance of the indicated surgery.

Penicillin is used routinely and no advantage can be seen in attempting the surgery without it. While there is no proof that it is a necessity, and

although successful reparative procedures on compound fractures without it have been reported, there are two cases on record in which gas gangrene and death followed reparative operations upon compound fractures without the use of the agent. No deaths or serious untoward results from sepsis have been reported in similar cases receiving penicillin therapy as an adjunct to the surgery.

Systemic administration of penicillin, 25,000 units intramuscularly every three hours is the basic therapy. Local instillation into joints, 1,000 units per cc. is supplemental. Otherwise no local therapy is used in extremity surgery.

Patients with compound fractures as a rule are receiving penicillin therapy in the Evacuation or Field Hospital when they are transferred to the Base. Therapy is reinstituted on admission to the Base Hospital and continued until five to ten days after the last traumatizing surgery (which may produce more devitalized tissue) until as outlined above, the wound has sufficiently healed and contaminated devitalized tissue is no longer in evidence.

SURGERY

The surgery is aggressive rather than passive. Wounds are explored to insure the adequacy of the initial surgery, fractures may be fixed internally and soft-part wounds may be sutured. But the success of the program depends upon the quality of surgical judgment and technic. Every case requires a decision as to the anesthetic; the extent of further excisional surgery; whether to use some form of internal fixation; the extent of closure of the compounding wound possibly aided by relaxing incisions or flaps; whether, where and how to drain; and the postoperative method of obtaining or maintaining reduction.

Five to ten days will have elapsed since initial surgery before the patient with a compound fracture is ready for reparative surgery. With adequate blood replacement, continuing penicillin therapy and good roentgenograms made in the Base Hospital, he is anesthetized in an operating room prepared for any indicated surgery, be it *excisional* or *reparative*. There, the Evacuation Hospital encasement and dressing are removed, the extremity prepared and draped and the wound inspected. A pneumatic tourniquet is frequently used not only to provide a "dry" operative field but to minimize blood loss on the table.

Wound Revision: The entire wound including the fracture site is exposed by gentle retraction and explored to insure the adequacy of the initial surgery. Incisions are enlarged if necessary to facilitate exposure. Any remaining foreign material, accessible foreign bodies, totally detached bone fragments or devitalized soft tissue are removed. Old blood clot is cleaned out. Means by which dead space may be obliterated or drained are considered. Further excisional surgery is not infrequently indicated. Failure to perform wound

revision soon after admission to the base is believed to account for many poor results seen in the past. Muscle tissue which appeared viable at initial surgery and, therefore, was not removed may have necrosed in the interim. When the remaining devitalized tissue of dirty wounds was not excised, wound sepsis with continuing local necrosis of living tissues was often established. Late wound exploration in cases of established sepsis has frequently revealed foreign material, or totally detached indriven fragments of cortical bone. Their removal plus proper reparative surgery was followed by subsidence of wound sepsis (Cases 1, 2 and 15). Reduction to the minimum of residual devitalized tissue is the most important step towards the minimizing of sepsis and is the keystone of the plan of management. When sepsis intervenes, reparative measures are doomed to failure, delayed or nonunion may follow, and wound healing will be postponed or prevented.

Fracture Management: The thorough wound visualization of reparative surgery affords the advantages of open reduction of fractures. Intervening soft parts are removed. Fragment ends caught in muscle are released. Rotated and twisted fragments are aligned. Complete appraisal of the problem at hand by direct vision as well as by roentgenogram is valuable in determining the means of obtaining and maintaining fracture reduction. The best possible fracture reduction is the objective of fracture management. In addition to the anticipated favorable anatomic result, stabilized fracture reduction eliminates the dead space of an unreduced fracture, and avoids traumatizing multiple manipulations or adjustments of traction in delayed efforts to effect reduction, thereby minimizing the chances of sepsis. In an effort to achieve the maximum fracture reduction, internal fixation is sometimes used under the following principles:

Internal Fixation: Internal fixation is by no means an objective of the program, and it is usually neither advisable nor possible because of severe comminution. However, the program permits the use of internal fixation with the limitations outlined below when it is *indicated* to maintain fracture reduction. Eighteen and eight molybdenum steel is relatively inert in the tissues and is not considered *per se* detrimental to wound healing. The fixation may be plating, multiple screws or wire loops.

The rigid stabilization of the fracture in reduction by a plate or multiple screws offers certain advantages (Cases 3, 4, 8, 11, 12):

1. Anatomic opposition and alignment anticipating faster bony union with no deformity.

2. The dead space and traumatizing manipulations outlined above are avoided.

3. Handling of the extremity for necessary subsequent wound care is facilitated.

4. Early joint motion and muscle exercise anticipating a more rapid return to function may be permitted.

5. The management of concurrent injuries which preclude traction and require repeated trips to the operating room is facilitated.

However, the use of internal fixation is limited by three factors other than comminution:

1. The desire to minimize intrawound trauma, *e.g.*, retractor pull, vessel ligatures—which creates additional devitalized tissue.

2. Interference with the covering of all exposed bone cortex with vascular soft parts (to be discussed under closure) (Case 5).

3. The desire to avoid periosteal stripping with its danger of massive sequestration which may be necessary to permit the application of a bone plate (Case 6).

When periosteum is stripped from bone, the outer cortex will die.[11] A basis for this statement is the experimental observation in dogs that the periosteal blood supply nourishes the outer third of the cortex of shafts of long bones.[12] If there is no sepsis, the dying bone is replaced by new bone as one process. But if sepsis is present reattachment of periosteum or other soft parts is prevented and the outer cortex becomes a sequestrum. Therefore periosteal stripping which deprives the outer cortex of bone of its nourishment is an important consideration in surgery in a known "infected" field. Practically, if the wound is appraised clean and the other factors are favorable, especially the availability of vascular soft parts, as in the arm or thigh, there is less hesitancy in stripping sufficient periosteum to permit the indicated surgery but if it is appraised "dirty"* or doubtful, the stripping is restricted or avoided.

Where the factors that might restrict its use are not unfavorable and the fracture permits, rigid internal fixation is frequently employed in order to gain the advantages of a well-reduced and stabilized fracture. Fixation through the compounding wound is at times practical but has the disadvantages of retraumatizing tissue and placing the metal on bone usually devoid of periosteum and at the bottom of dead space created by excision of devitalized muscle. Therefore, for plating, a separate standard approach to the fracture which permits covering of the bone and metal by periosteum and vascular soft parts is advisable (Case 4).

Every refinement in the technic of internal fixation is considered important. There must be intimate contact of the fragments; plate should be sufficiently long (Murray[13] recommends that the length of the plate be five times the diameter of the bone at the fracture); drill holes should be only slightly larger than the shaft of the screw, less the threads, preferably at right angles to the bone and wobbling of the drill or a drill bit at an angle should be avoided to prevent scoring of the drill hole. (Electrically driven drills require extreme caution to prevent burning of the bone); screws

* The term "dirty wound," as a contrast to clean wound is in common usage in this Theater and is herein used to describe the wound which is visualized to contain gross, unexcised devitalized tissue, is discharging pus, often foul-smelling, from the depths of the wound, or is covered by a gray, slimy purulent exudate. Cardinal signs of inflammation are not necessarily present in the dirty wound. When they are present, the wound is said to present "invasive infection."[16]

should be held "true," inserted by a steady hand and be long enough to protrude through the opposite cortex. Oblique screws across the fracture in a plane at or near 90 degrees from that of the plate will increase the rigidity.

In actual practice when internal fixation is deemed indicated multiple screw (two or more) fixation is frequently used (Cases 7, 8 and 11). Many fractures by their obliquity lend themselves to it, little or no additional periosteal stripping is required to permit placement of the screws, and intrawound trauma is not excessive. If the fracture does not permit rigid fixation because of comminution, one or more wire loops may be used to hold major fragments in approximation. These can usually be placed without additional periosteal stripping, a factor of particular importance in a wound with recognized established sepsis. In comminuted fractures with segmental bone loss, wire loops permit approximation of the major fragments (Cases 9 and 10).

Bony union is a prime consideration in any fracture and contact of the fragments greatly enhances the chances of union. Therefore the shortening of an extremity to overcome segmental loss and obtain contact of fragments is often a justifiable indicated procedure that is permitted by reparative fracture surgery. Nerve trunk or muscle group deficits associated with a fracture may indicate the deliberate removal of attached bone fragments and shortening of the extremity, thereby permitting restoration of continuity of all the severed major structures projected towards the maximum functional restoration of the extremity instead of a good fracture result as determined by the roentgenogram.

Wound Closure and Drainage: Wound closure is premised upon adequate initial surgery resulting in a clinically clean wound requiring little or no wound revision or traumatizing surgery and upon the feasibility of obliterating or draining dependently the residual dead space. The lag-period between initial and reparative surgery permits drainage of the products of injury necrosis. If initial surgery has been inadequate, resulting in a clinically dirty wound requiring extensive excisional surgery at wound revision, wound closure must be staged until after an additional lag-period for open drainage.

The hazards of an open wound in a compound fracture are the sequestration and sloughing of exposed bone cortex, tendon and fascia, plus reinfection at dressings and slow wound healing by granulation. The advantage of an open wound is continuing drainage from the depths of the wound until healing by granulation has sealed-off the fracture site. The gaping wound forms a natural channel for drainage. However, when it is not dependent and sepsis intervenes, there may be pocketing, puddling or pooling of pus in the fracture site or adjacent fascial planes with continuing local necrosis of the collagenous tissues.

Reparative surgery of compound fractures recognizes and attempts to overcome by wound closure the hazards of the open wound but also recognizes the advisability of a means of egress for the possible septic breakdown of any residual devitalized tissue not yet separated and of a contaminated hematoma

in unobliterated dead space. In the uninfected field, *e.g.*, the simple fracture or following a clean surgical operation, body processes will absorb devitalized tissue and blood clot. In the infected* field the same absorption might occur but the complete closure of wounds of compound fractures is justified only when the pabulum for wound sepsis is *nil*. A deep abscess about the fracture site underneath a sutured or healed epithelial bridge may produce irreparable damage. Therefore, an increased margin of safety can be obtained by providing drainage, dependent if possible, utilizing wounds or counterincisions as indicated. Drains are inserted so as not to cause tissue necrosis and are removed between the third and tenth day depending upon the drainage indications before rigid sinus formation occurs.

The problem of closure of the compounding wound is approached with the major objective of covering exposed bone cortex, tendon and fascia with healthy soft parts and the minor objective of reducing skin defects to a size that is compatible with *adequate* drainage. The sliding or rotation of flaps is often employed to gain these objectives (Cases 11 and 13). The hazard of periosteal stripping finds its antithesis in the value of covering bone exposed by trauma. Soft parts must adhere to the bony cortex to permit its "revascularization," whereby the dying bone may be absorbed and replaced by new living bone. Otherwise sequestration is inevitable (Case 15). Therefore, wound closure is designed to obviate the hazards of exposed bone cortex the salvage of which is probably the most important attainment of reparative surgery of compound fractures (Cases 10, 11, 13 and 14).

When soft-part masses fall over and protect structures that are vulnerable to exposure, *e.g.*, the muscles of the thigh over the femur, the major hazard of the open wound is removed and surgical closure is of less importance. The open wound may be the optimum method for free drainage and is utilized when closure, complete or partial, affords no definite advantages. The closure of a small wound compounding a fracture of the femur is inconsequential as the soft parts will be healed before the bone unites.[2] The open wound is particularly advantageous for drainage following traumatizing surgery, *e.g.*, extensive wound revision for dirty wounds or difficult internal fixations (Cases 3 and 4). In such cases, skin suture is avoided or staged. However, skin defects usually may be reduced and still permit adequate drainage. When the wound is clean and requires no traumatizing surgery, and when dead space is at a minimum, skin may be sutured completely or with a small drain of dry fine-mesh gauze or soft rubber tissue emerging through the most dependent portion of the wound or a counterincision (Cases 8, 9 and 10). When two wounds compound the fracture, one may be closed completely and the other (usually the more dependent) left open or partially closed, with or without drainage material. Surgical limitations, *i.e.*, tension, dead space or difficult dependent drainage as in anterior wounds over fractures of the tibia, may preclude wound suture and

* Infected, herein, denotes only the recognized presence of a bacterial flora capable of establishing wound sepsis in the presence of dead tissue.

the wound may require loose packing anticipating healing from the bottom by granulation (Orr method) (Cases 7, 8 and 14), but in many of these, partial wound closure may be employed to cover exposed cortex of bone. Partial wound closure in reducing the magnitude of compounding wounds facilitates the sealing-off of the fracture site by healing processes rather than attempting the immediate conversion of the compound to a simple fracture and, therefore, it is frequently employed to reduce the size of defects of the compounding wounds. The reduction to a minimum of skin defects minimizes scar, promotes earlier wound healing and leads to improved functional results.

Postoperative Management: Immediate adequate reduction and stabilization of the fracture is essential to reduce dead space, prevent the continuing trauma of fragment ends, and provide wound rest to promote wound healing In many cases sheet wadding and plaster encasements for immobilization of the fracture in reduction provide pressure dressings for the control of dead space and wound edema. When skeletal traction is the method of choice for postoperative fracture management, the wounds are supported by bulky dressings and elastic bandages. Variations of, and adjuncts to, .skeletal traction methods are frequently employed in obtaining and maintaining fracture reduction, *e.g.,* Army leg splint, "Navy" traction, two-wire traction[14] (Plate 1). Anesthesia is often continued until the completion of the traction set-up on the ward permitting immediate manual reduction verified roentgenologically. By this plan, reduction in traction is quickly obtained, and it is maintained by the skeletal traction. Fractures fixed internally are also immobilized externally by plaster or skeletal traction. In the postoperative management of internally stabilized fractures of the femur, skeletal traction affords added protection and permits adequate wound care, early knee motion and physiotherapy.

The case reports and illustrations which follow are presented to illustrate the details of the principles of reparative surgery as applied to compound fractures. Each case demonstrates the application or omission of one or more of the principles covered in the manuscript. While the majority of the cases in the group illustrate results to be anticipated by reparative surgery, cases illustrating certain pitfalls that occurred during the formative stage of the program are included to emphasize certain conclusions.

Internal fixation has been used in nine cases, herein reported, including two cases of wire approximations of major fragments. The predominance of internal fixation in these reports should not be interpreted to mean that the method is employed in the majority of cases, for such is far from true. The group of cases included illustrate the *indications* for the method and concurrently, other principles. Skeletal traction (Plate 1-a-e) is the usual method of obtaining and maintaining fracture reduction when traction is necessary.

Penicillin therapy, unless otherwise stated, and blood replacement therapy were used in each case according to the plan outlined in the manuscript.

PLATE I

A. Fracture of the femoral shaft in the midthird in balanced suspension skeletal traction utilizing the Army leg splint with the Pierson attachment and a Kirschner wire through the tibial tubercle. The leg splint.—Pierson method is used in the majority of cases.

B. Fracture of the upper third of the femur in balanced skeletal traction, utilizing the "Navy" method. It is an excellent method for upper third fractures, with high thigh or posterior wounds.

C. A ward of fractures of the upper third of the femur treated in balanced skeletal traction, employing the "90-90-90" method (the hip, knee and ankle joint position). After a few weeks in this position during which posterior wound management and fracture reduction is effected, the leg splint—Pierson method is substituted.

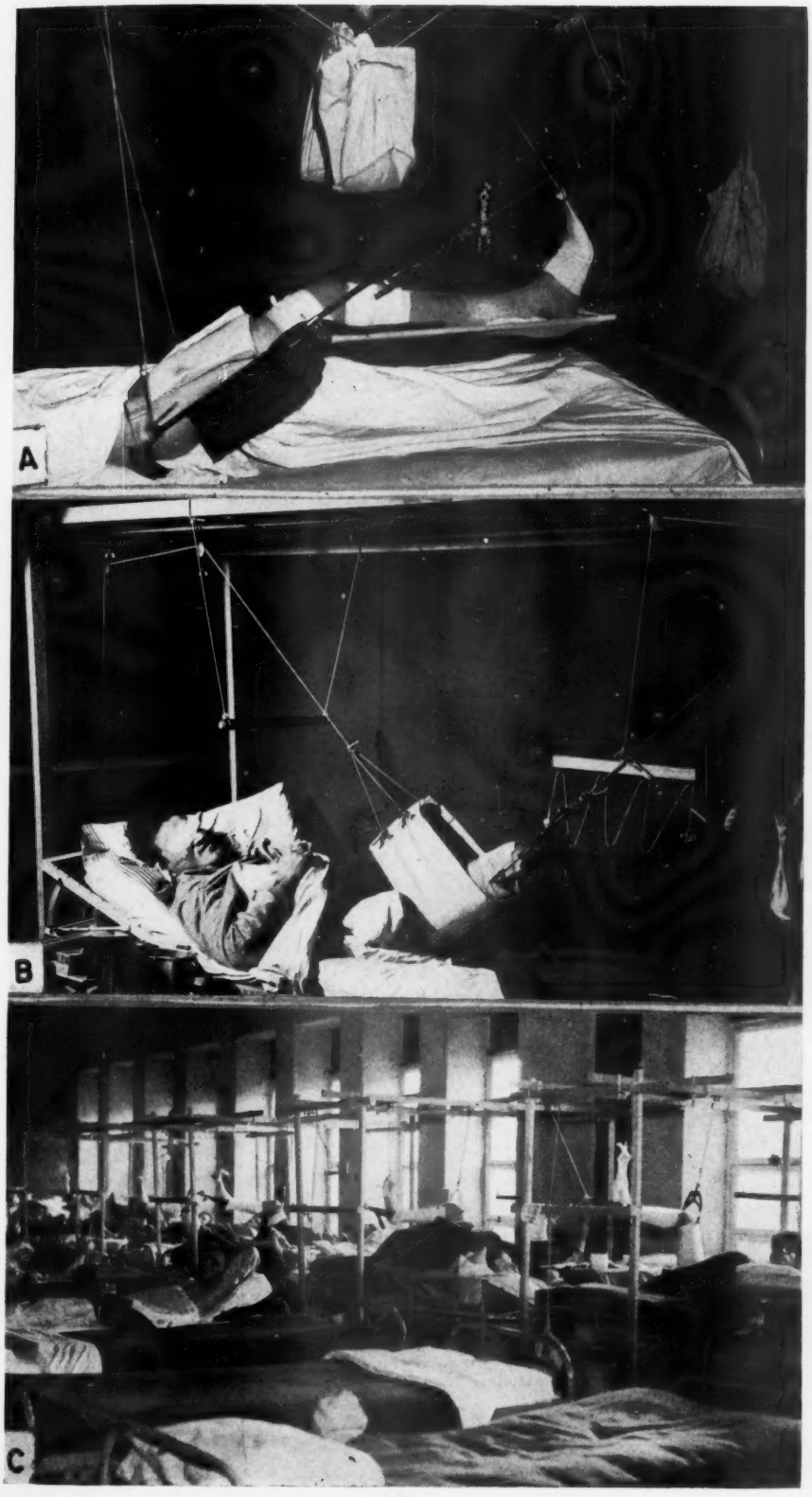

A
B
C

PLATE I (CONTINUED)

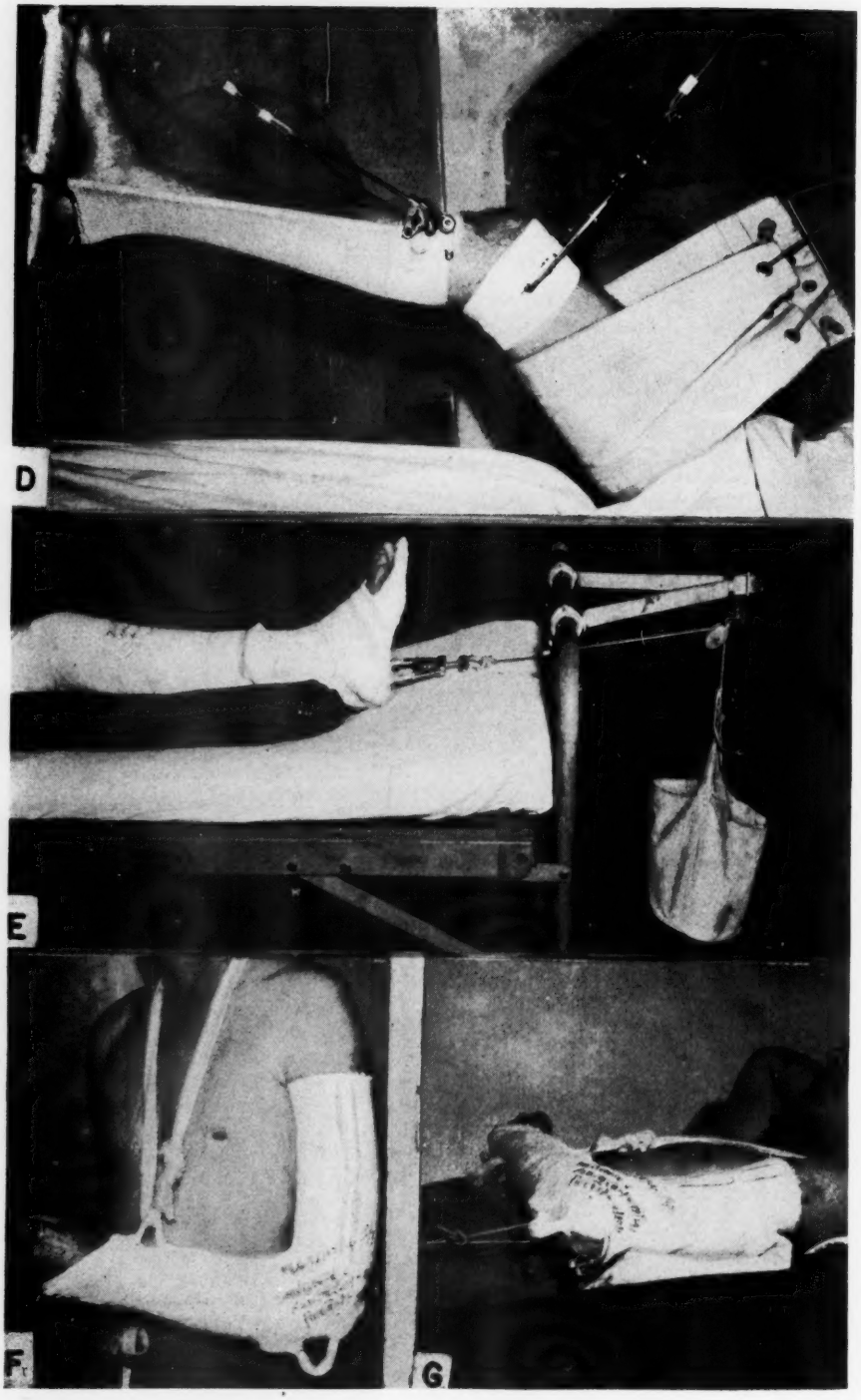


PLATE I (CONTINUED)

D. Two-wire, or double skeletal traction, here used as an adjunct to the "Navy" method for management of a fracture of the lower third of the femur. The two-wire method as illustrated is almost a routine for displaced lower third fractures.

E. "Encasement Traction," a modification of skeletal traction through the os calcis, is a valuable method of maintaining adequate reduction of fractures of both bones of the leg.

F. The "hanging cast"—the most frequently employed method for obtaining and maintaining reduction of fractures of the humerus.

G. A folded towel for support of the arm and traction over a pulley at the foot of the bed permitted by the loop of plaster are employed during temporary recumbency after the reparative surgical procedure.

PLATE II

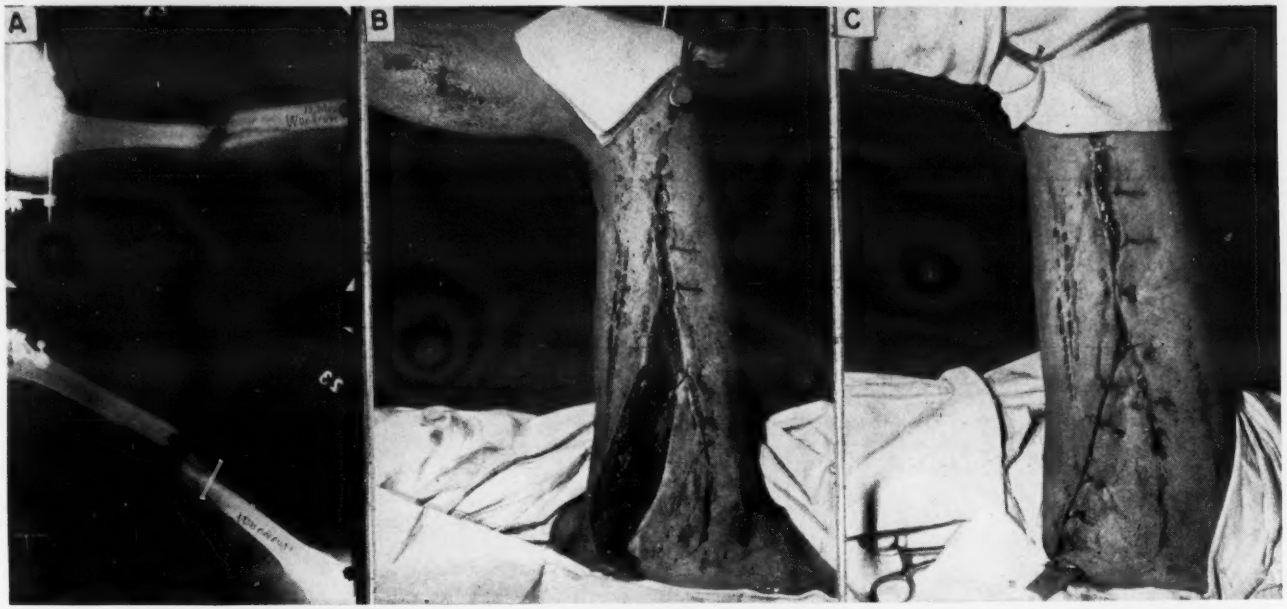
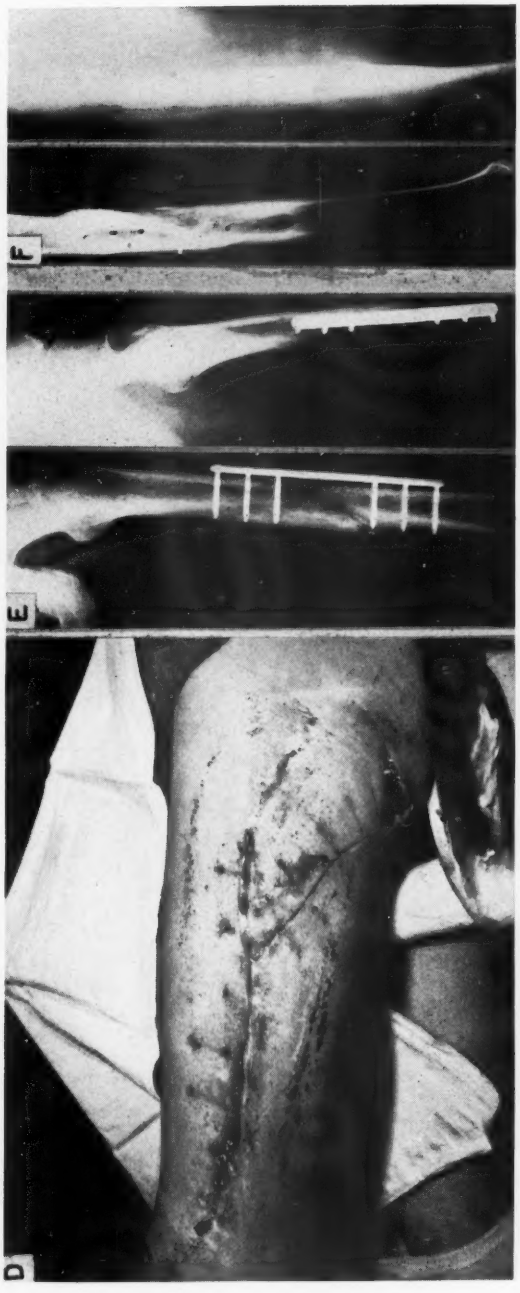


PLATE II.—Case 3: A. Roentgenograms, 13 March, 1944, one month after injury, with the extremity in skeletal traction, revealing distraction and gas abscess formation.

B. Partial wound closure and gaping dependent open wound for drainage at reparative surgery on 15 March, 1944.

C. Staged closure of the remaining portion of posterior wound over a small drain on 21 March, 1944.

PLATE II (CONTINUED)



D. 28 March, 1944. Wound healing has been obtained, except for the small granulating areas in the old compounding wound and at the proximal end of the drainage incision.

E. Roentgenograms showing the internal fixation and suggestion of sequestrum formation. Made in Z of I in July, 1944.

F. Roentgenograms showing end-result.

PLATE III

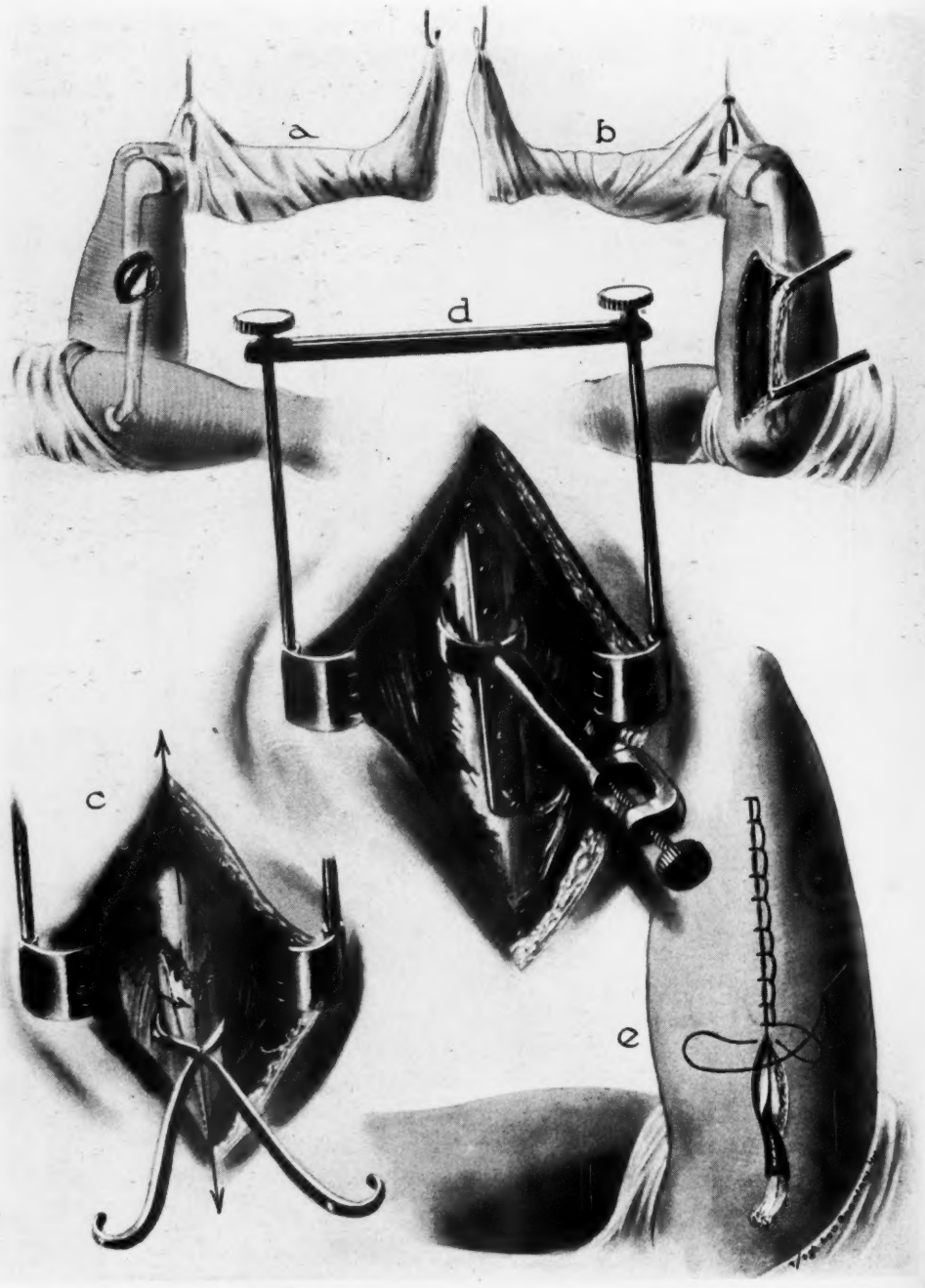


PLATE III.—Case 4: a. Compounding wound.

b. Posterolateral approach.
c. The fracture reduction.
d. Internal fixation.
e. Closure of the operative wound, with drainage. The artist has failed to depict comminution and an obliquity in the fracture.

PLATE IV

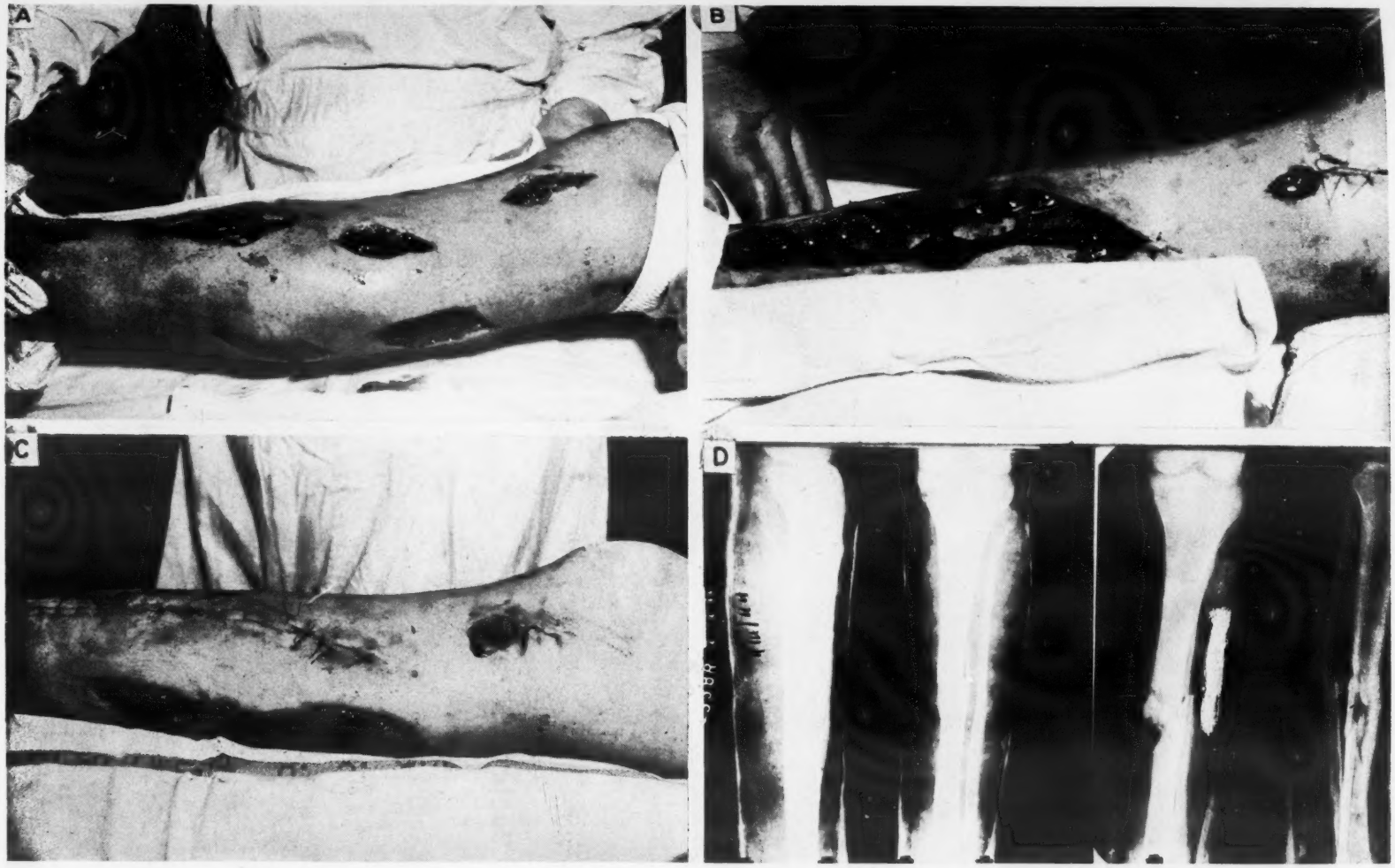


PLATE IV.—Case 5: A. The wounded extremity prepared for reparative surgery on 3 April, 1944.
B. The fracture stabilized by the plate passing over a large fragment.
C. The closed operative wound and the converted relaxing incision through which drainage was planned.
D. Roentgenograms made pre- and postoperative. Note the hair line reduction of the fibula in the postoperative films (on left). Conversely, plating of the fibula will produce adequate reduction of a severely comminuted tibia.

PLATE V

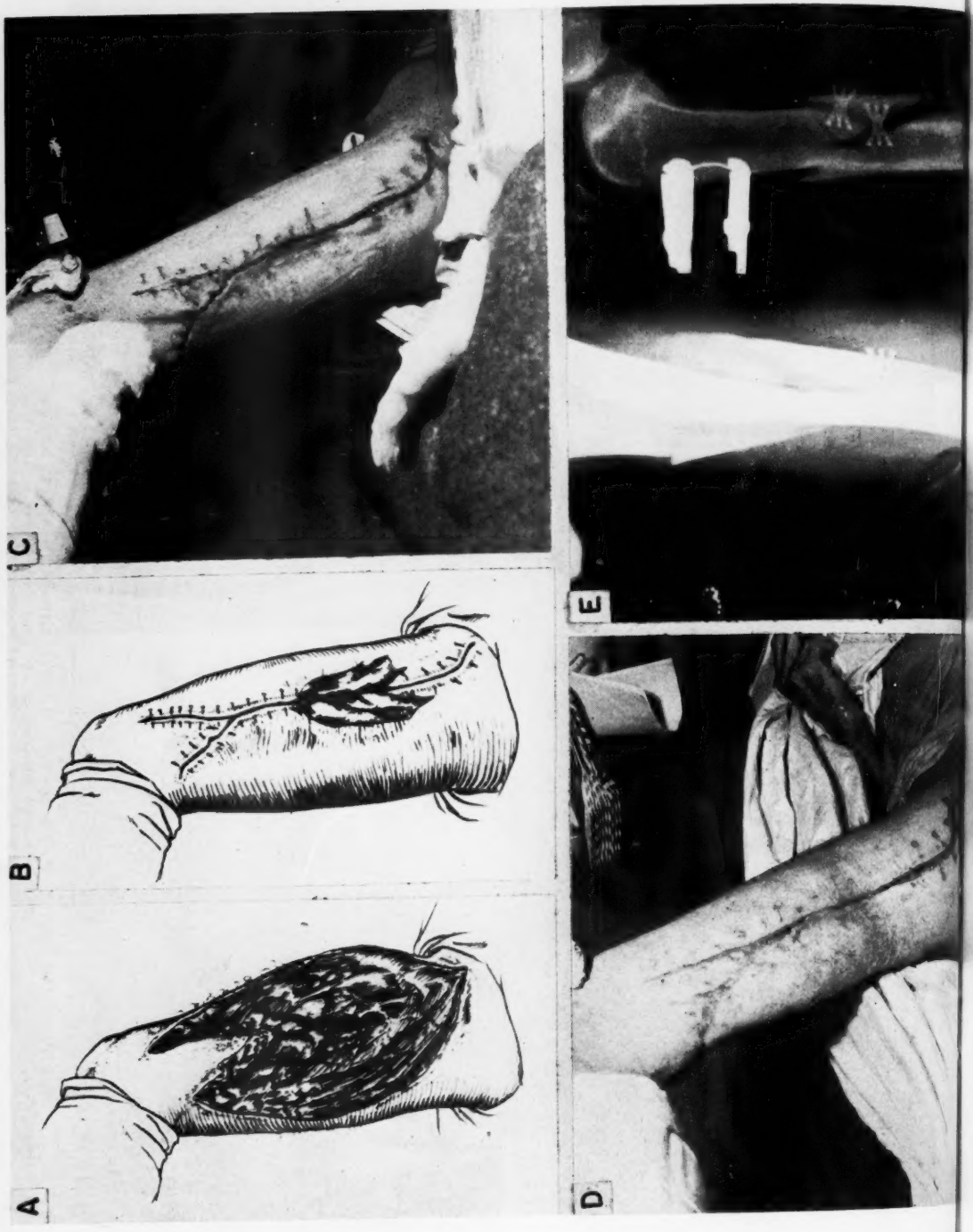


PLATE V.—Case 6: A. Drawing of the huge wound as it presented itself at operation.

B. Drawing of the partial closure with fine-mesh gauze drainage to residual dead space.

C. In two-wire skeletal traction on the Ward 26, October, 1944. Wound healing is progressing satisfactorily.

D. 17 November, 1944, one month postoperative, complete wound healing has been obtained.

E. Roentgenograms, 24 October, 1944, showing adequate apposition and good alignment. This reduction was maintained until bony union occurred. Note the "lifting" of the distal fragment into apposition in the lateral view.

PLATE VI

A

B

PLATE VI.—Case 7: A. 15 July, 1944. The former defect which has filled with granulations, without sinus to bone.

B. 15 July, 1944. The healed operative incision for the plating of the fibula.

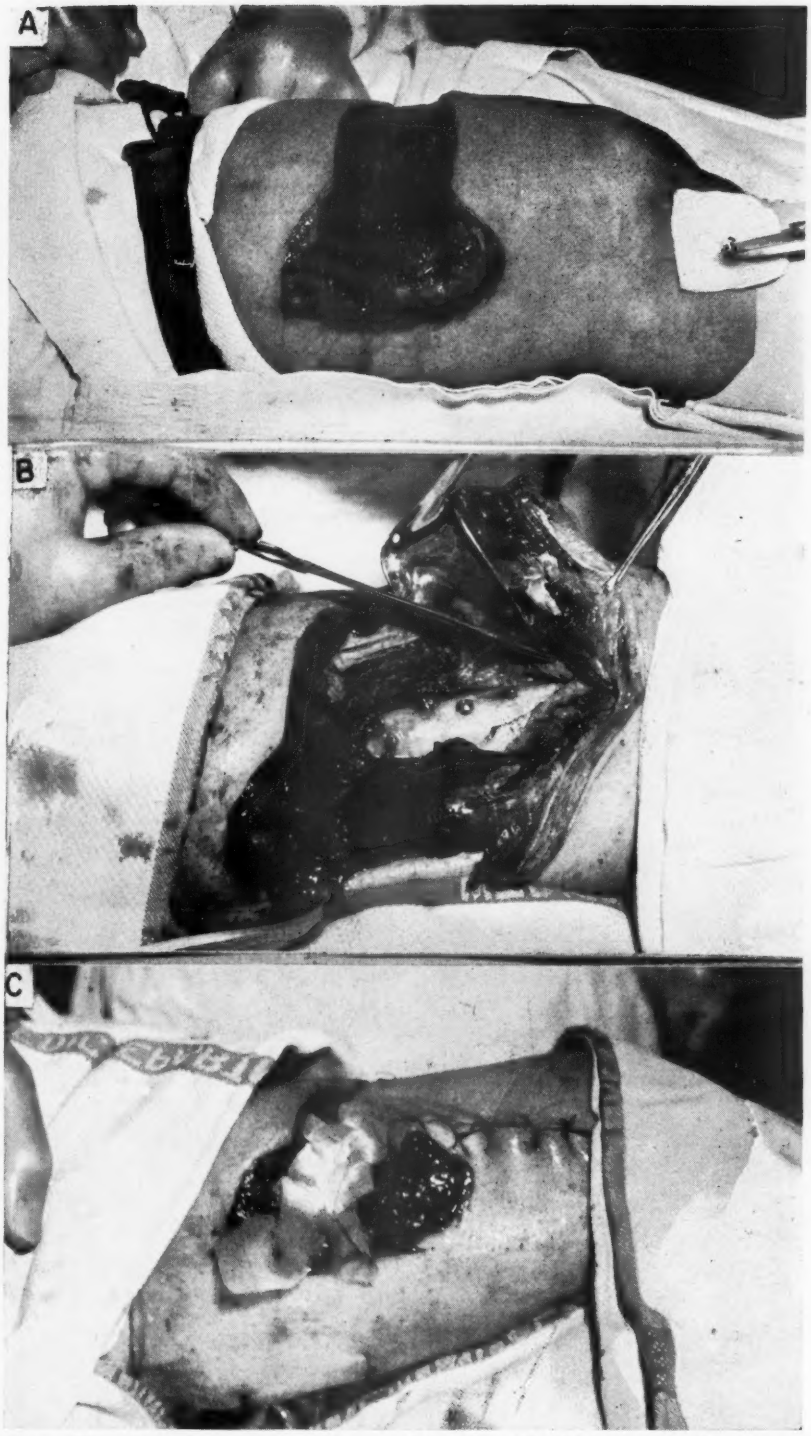


PLATE VII.—Case 8: A. Compounding wounds of the right thigh at reparative surgery, 9 April, 1944.

B. The internal fixation by four screws. Minimal periosteal stripping was required.

C. Partial closure and loose packing of the dead space, with dependent drainage through a separate incision in the posterolateral fascial plane.

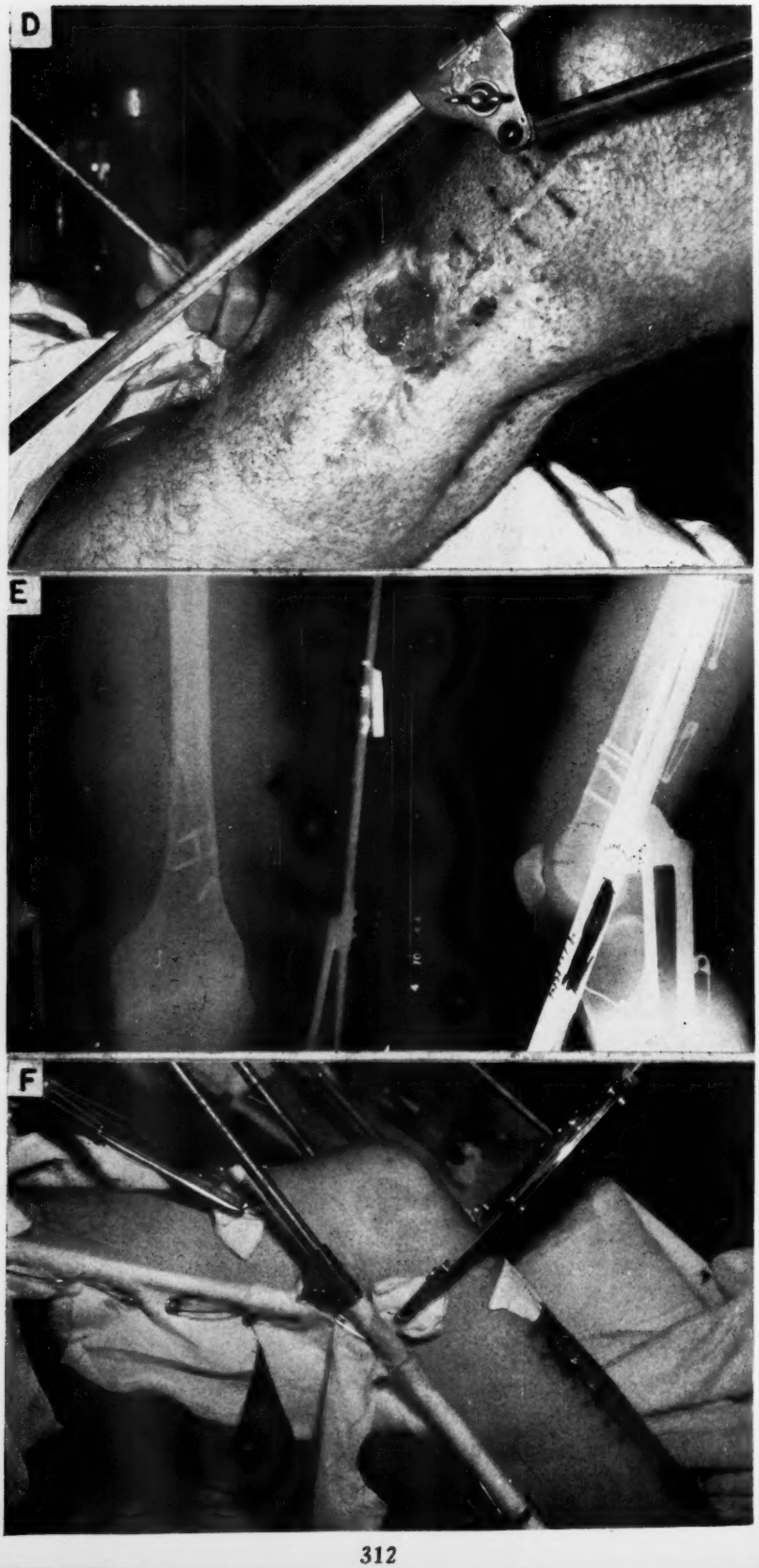

D
E
F

PLATE VII (CONCLUDED)

D. Sutured and drainage wounds are firmly healed and the dead space has filled with granulations, without sinus to bone. 6 July, 1944.

E. Roentgenograms of right femur made postoperative.

F. Left lower extremity in two-wire traction showing the healed anterior thigh wound. The posterior wound was also healed. 6 July, 1944.

G. Roentgenograms of left femur in two-wire traction.

H. The patient fully ambulatory with all wounds healed and 90 degrees knee flexion (excellent for lower third battle fractures) in early 1945.

PLATE VIII

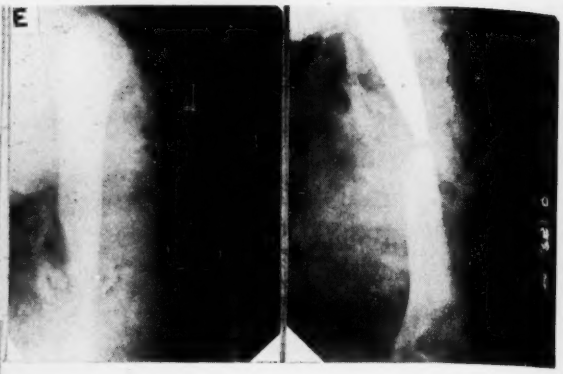


PLATE VIII.—Case 9: A. Lateral wound in operating room 30 October, 1944.

B. Medial wound in operating room 30 October, 1944. Note large blood clots in the wound.

C. Sutured lateral wound at reparative surgery 30 October, 1944.

D. Grafted medial wound 30 October, 1944.

E. A. P. and lateral views of fracture in plaster. Approximately one-inch bone deficit has been overcome by the wire loop fixation.

PLATE IX

A

B

PLATE IX.—Case 10: A. The united fracture of the humerus in July as shown roentgenologically. The humerus was shortened about one and one-half inches at reparative surgery to obtain contact of fragments.

B. The healed grafted area over the humerus. The graft had been performed through a large window in the spica, hence, the raw area on the chest had not been grafted.

PLATE X

A

B

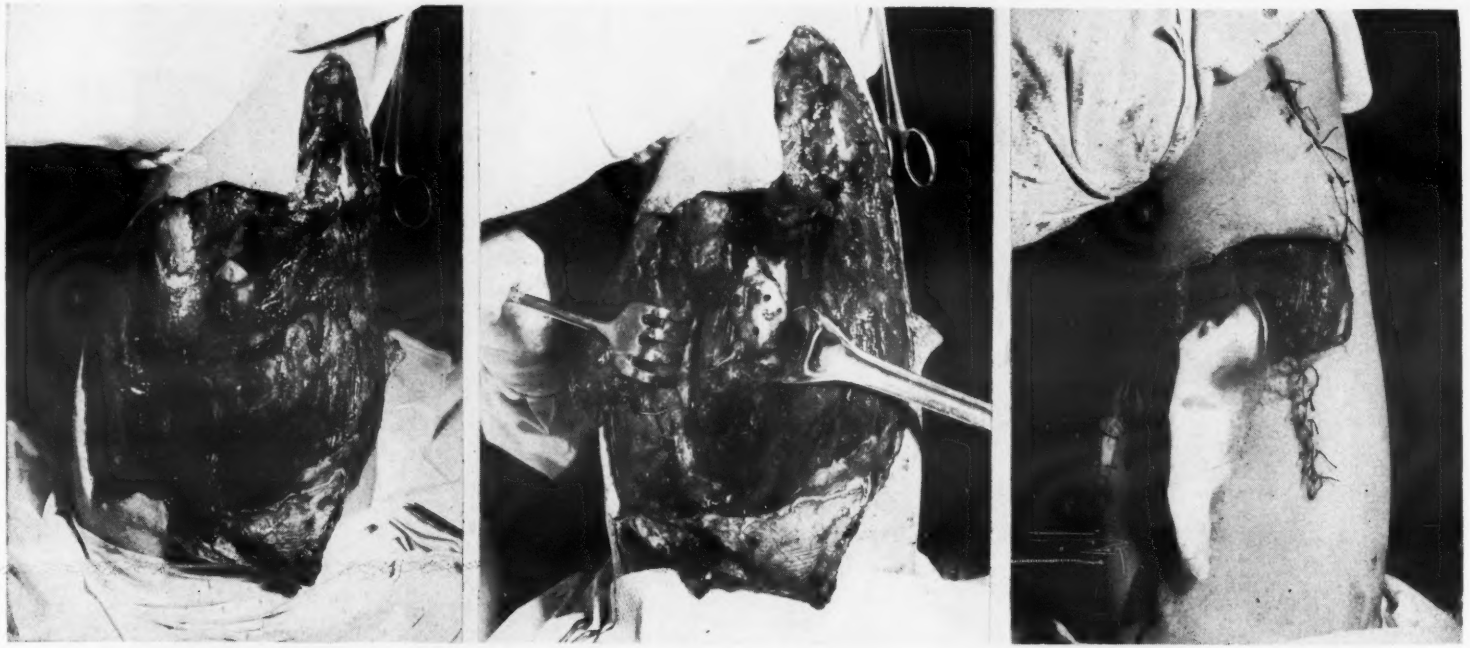
C

PLATE X.—Case 11: A. 15 July, 1944, four weeks after reparative surgery. Healed sutured wound over the tibia and the granulating relaxing incision. The latter might have been split-skin grafted.

B. The healed lateral wound through which drainage was established for a few days.

C. Roentgenograms made pre- and postoperative. The upper screw missed the drill hole in the distal cortex.

PLATE XI



A B C

PLATE XI.—Case 12: A. Exposure of massive wound, with thigh in the "90-90-90" operative position. Note the projecting bone in wound.

B. Fracture stabilized by multiple screw fixation, with no additional periosteal stripping.

C. Partial wound closure and drainage of residual dead space with dry fine-mesh gauze. The sutured areas possibly represent surgical extensions of the wound for adequate exposure. The remaining raw area probably represents the skin loss at the time of wounding.

PLATE XII

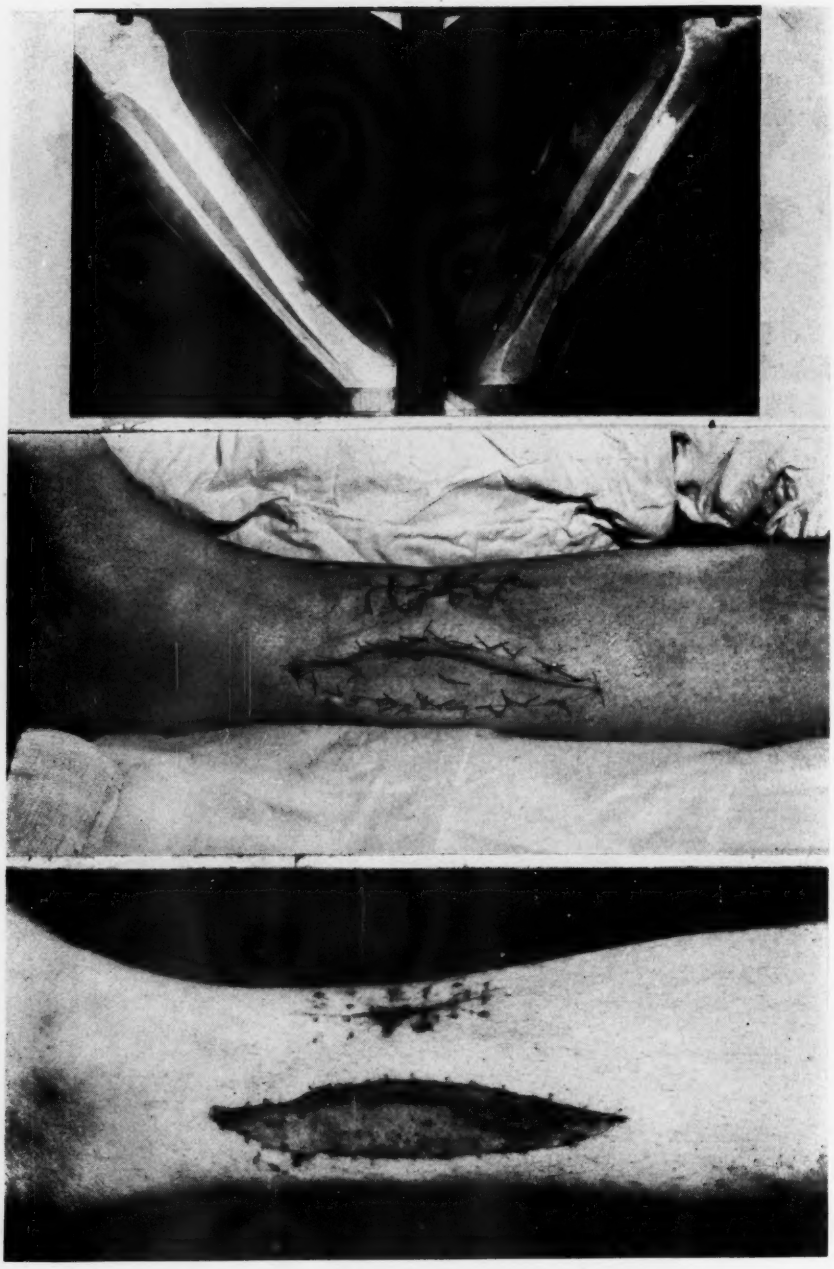


PLATE XII.—Case 13: A. Roentgenograms made at the Base Hospital.
B. Sutured compounding wound and skin-grafted relaxing incision of reparative surgery.
C. The healed wound and 95% take on skin graft, two weeks after reparative surgery. Sound wound healing followed shortly. The patient returned to duty in this Theater.

COMPOUND BATTLE FRACTURES

PLATE XIII

A

B

C

PLATE XIII.—Case 14: A. Roentgenograms made 16 March, 1944.

B. The leg wound in the operating room just prior to reparative surgery. Note the pneumatic tourniquet. Blood loss from upper tibial fractures is usually severe.

C. The healed sutured projections of the wound and the clean fracture cavity on 23 March, 1944. Sutures were removed, the cavity loosely filled with dry fine-mesh gauze and a plaster encasement applied, anticipating no wound disturbance for several weeks.

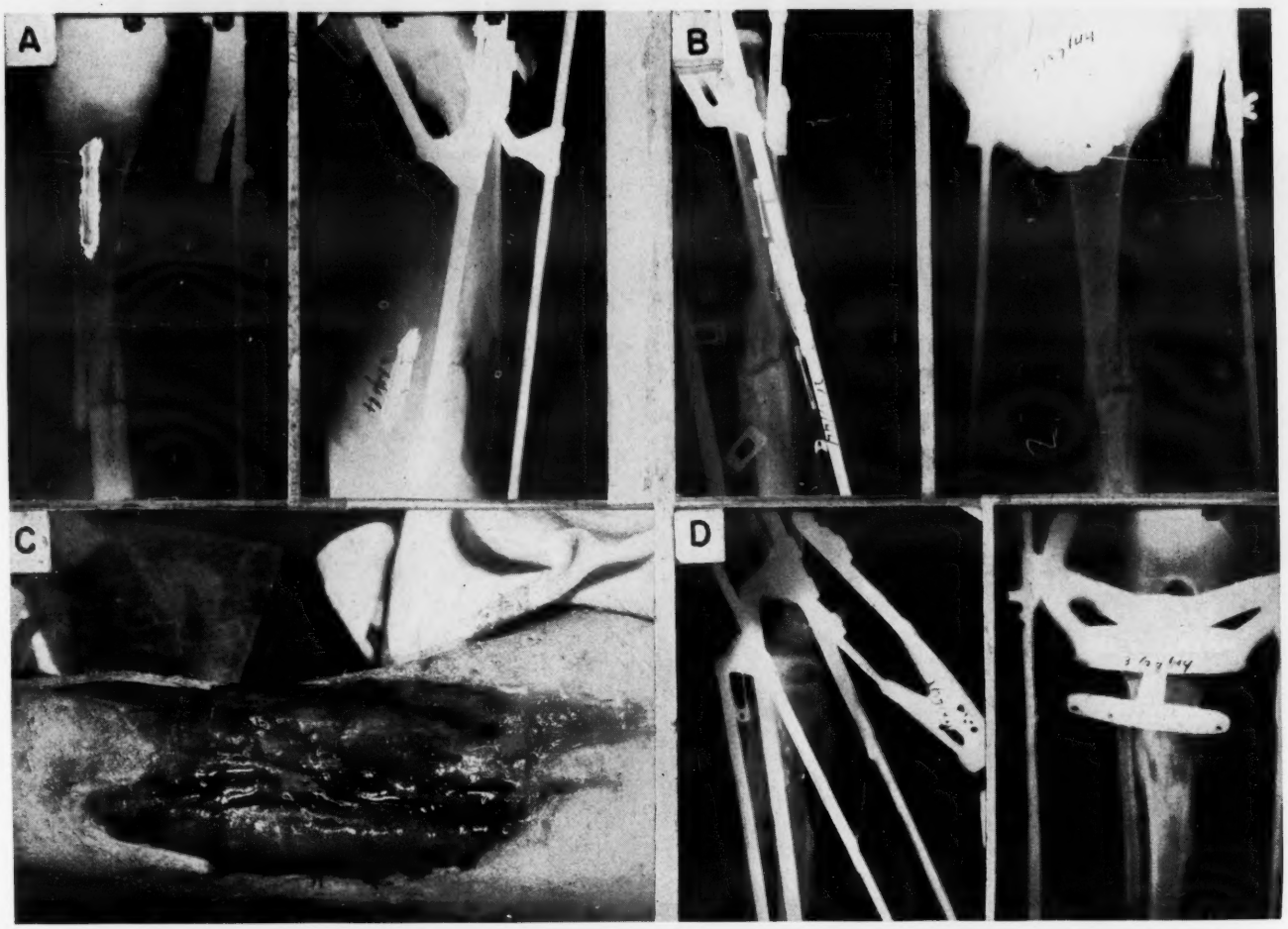


PLATE XIV.—Case 15: A. A. P. and lateral views of the femoral fracture in skeletal traction on 4 February, 1944. Improved reduction was obtained later.
B. A. P. and lateral views 27 March, 1944, showing the partially united fracture with massive sequestrum formation.
C. The large raw anterior thigh wound on 6 April, 1944. The fracture site was open and pus puddled in the depths of the wound.
D. A. P. and lateral views of fracture of the tibia.

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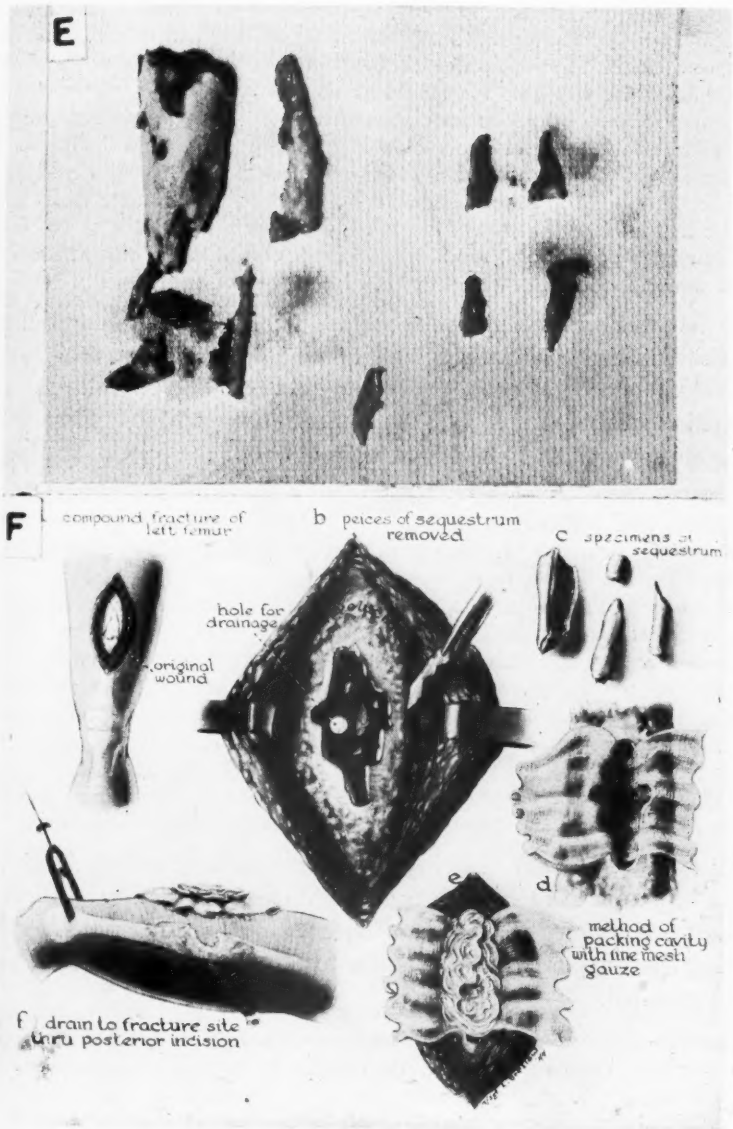
PLATE XIV (CONTINUED)



E. Sequestra removed from the femur (left) and tibia (right), at operation on 6 April, 1944.

F. Drawings of the reparative surgery on the femur.

PLATE XIV.—Case 15: A. P. and lateral views of the femoral fracture in skeletal traction on 4 February, 1944. Improved reduction was obtained later.

B. A. P. and lateral views 27 March, 1944, showing the united fracture with massive sequestrum formation.

C. The large anterior thigh wound on 6 April, 1944. The fracture site was open and pus puddled in the depths of the wound.

D. A. P. and lateral views of fracture of the tibia.

ILLUSTRATIVE CASE REPORTS*

Case 1.—*Diagnosis:* Penetrating wound of left knee joint, with fracture of medial femoral condyle, incomplete.

Wounded: July 1, 1944, 2100 hours, by high explosive shell fragment which embedded in the medial femoral condyle through the articular surface.

Initial Surgery: July 2, 0400 hours, time-interval, seven hours. Through a two-inch arthrotomy incision, the foreign body was removed, the joint cleaned and the synovia and capsule closed. Penicillin was instilled into the joint and given systemically. A plaster encasement was used for immobilization.

Reparative Surgery: Soon after admission to the Base, wound and joint sepsis was found to be established. Maggots crawled from the joint. The joint was reëxplored and a piece of khaki cloth was found buried in the defect in the femoral condyle. Removal of it and devitalized cartilage followed by lavage, joint closure, local and systemic penicillin and immobilization in a hip spica, produced a subsidence of the infection. A late follow-up, April 5, 1945, revealed 90 degrees of painless motion at the knee and all wounds healed.

COMMENT: Incomplete initial surgery allowed foreign material to remain. Established sepsis indicated a surgical approach. At wound revision, the khaki cloth and remaining devitalized cartilage were removed, permitting indicated reparative surgery. The completion of excisional surgery soon after admission to the Base Hospital is the keystone of the plan of management.

Case 2.—*Diagnosis:* 1. F. C. C. left tibia, upper half. 2. F. C. C. of right femur, upper third (not here considered).

Wounded: February 18, 1944, 0800 hours, by high explosive shell fragments which penetrated the left leg fracturing the tibia.

Initial Surgery: February 18, 1944, 1030 hours. Time-interval, 2.5 hours. Débridement, vaselined gauze dressing and a plaster encasement.

Reparative Surgery: The primary encasement was changed soon after admission and again on March 13, 1944, when it was noted that the drainage was purulent and foul-smelling. An incipient osteomyelitis was thought to be present. On March 30, 1944, the wound and fracture were explored. Several dead unattached indriven fragments of bone were removed. The wound was loosely filled with fine-mesh gauze and an encasement applied. On May 1, 1944, at change of encasement, the wound was clean, there was no foul drainage, and there was clinical evidence of bony stability.

COMMENT: Totally detached bone fragments are devitalized tissue that should be removed at initial surgery. Wound revision as the primary step in reparative surgery insures the adequacy of initial surgery. If this fracture site had been explored on admission to the Base, a septic tibia might have been prevented.

Case 3.—*Diagnosis:* F. C. C. left femur and patella.

Wounded: February 16, 1944, 1045 hours, by a high explosive shell fragment at Anzio, Italy.

Initial Surgery: February 16, 1944, 2320 hours. Time-interval, 1235 hours. All wounds débrided and metallic foreign body removed from the left knee, 1.5 hip spica applied. He was evacuated to the Base on February 19, 1944, by L. S. T.

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* The reported cases were managed by the staffs of Forward and Base Hospitals of the Mediterranean Theater of Operations. It is regretted that because of insufficient information adequate acknowledgment cannot be given to the surgeons who produced the splendid results. The photographs and artist's drawings were produced by detachments of the Museum and Medical Arts Service.

Reparative Surgery: On February 22, two days after admission to the Base Hospital, exposure of the wound revealed incomplete initial surgery, requiring further excisional surgery. The wound was left open. Skeletal traction was instituted.

On March 14, 21 days after wound revision, he appeared sick and washed-out, and had a continuous low grade fever. The fracture site was visible through a gaping lateral wound. Skeletal traction had failed to obtain fracture reduction. Roentgenograms showed the fracture in distraction, and the seat of a gas abscess. Three thousand cubic centimeters of blood had been administered in the Base Hospital. Operation March 15, 1944: An abscess in the posterolateral plane of thigh, pocketing in the proximal portion, was incised and drained. Totally loose bone fragments were removed, and the fracture was fixed in reduction by a bone plate. After excision of the old wound edge and granulation tissue, the exposed bone, including the fracture site, was covered by partial wound closure. The fracture site and fascial plane were adequately drained by the remaining gaping incision. Two thousand cubic centimeters of blood were given on the day of surgery and penicillin therapy in adequate dosage was instituted. On March 21, 1944, six days later, the wound was found to be clean and was sutured over a Penrose drain emerging at its proximal most dependent portion.

Postoperative course was not eventful. The drain was removed on the seventh postoperative day. A minimal amount of purulent drainage continued intermittently for several weeks. On May 2, 1944, there was no drainage site. A small sequestrum was suggested by late roentgenograms. The patient was evacuated to the Zone of Interior in a plaster encasement in mid-May.

In the Z. of I., solid bony union in anatomic alignment and wound healing followed. There was some absorption about one screw, therefore, the metal was removed. The wound of this procedure healed *per primam.*

COMMENT: This septic fracture developed following inadequate initial surgery. The fracture site was the seat of dead space and gas abscess formation. Drainage of the septic process by a lateral wound had been inadequate and a pocket of pus had formed in the posterior proximal thigh. At reparative surgery, sequestra were removed and the dead space of an unreduced fracture was obliterated. The fracture was stabilized in reduction and sufficient wound closure was done to cover all exposed bone. The wide-open posterior wound provided dependent drainage for the residual dead space which was further reduced by the staged closure six days later.

By reparative surgery, sepsis was controlled, the unreduced fracture was stabilized, and bone and wound healing were obtained.

Case 4.—*Diagnosis:* F. C. C. of femur.

Wounded: March 10, 1944, 1500 hours, by a high explosive shell fragment which penetrated the left thigh medially, fracturing the femur in the midthird.

Initial Surgery: March 10, 1944, 1900 hours. Time-interval, four hours. Débridement and removal of foreign bodies, loose fine-mesh gauze drain and dressing and plaster encasement.

Reparative Surgery: On the 19th of March, nine days after wounding, and two days after admission to the Base Hospital, the fracture was approached through a posterolateral incision, passing between the vastus lateralis and the biceps femoris, and stabilized in reduction by a bone plate. An additional screw was inserted through the compounding medial wound. The compounding wound was closed without drainage. The operative approach was closed over a soft Penrose drain. The extremity was placed in skeletal traction in a Thomas splint and Pierson attachment. The drain and sutures were removed on the tenth postoperative day. Healing was excellent, and the drainage area was dry on April 13, 1944. Beginning about April 1, 1944, active and passive knee

motion were permitted and quadriceps exercises were encouraged. In mid-April a 1.5 hip spica was applied for transportation to the Zone of Interior. The fracture went on to union and the wound remained healed. The range of knee motion by early 1945 was practically normal. In March, 1945, he returned to duty in a motor pool at a large General Hospital.

COMMENT: A standard anatomic plane approach was used, which permitted the bone exposed by surgery to be covered by healthy soft parts and also permitted dependent drainage. The fracture was anatomically reduced and stabilized, which permitted the necessary handling of the extremity for the removal of drain and sutures. The procedure permitted early knee joint motion and quadriceps exercises. The patient was evacuated to the Zone of Interior approximately one month after wounding. Treatment of the fracture by skeletal traction would probably have given adequate reduction but joint exercises would have been delayed and approximately three months hospitalization would have been required in a busy Theater of Operations.

Case 5.—*Diagnosis:* F. C. C. right tibia and fibula.

Wounded: March 27, 1944, 0500 hours, by high explosive shell fragments penetrating right leg (also injuries of other extremities) fracturing the tibia and fibula in the midthird.

Initial Surgery: March 27, 1944, 0900 hours. Time-interval, four hours. All wounds débrided, foreign bodies removed, sulfa crystals, vaselined gauze dressing and plaster encasement.

Reparative Surgery: On admission, March 31, 1944, his hematocrit was 22. Twenty-four hundred cubic centimeters of blood were given over a three-day period. At operation, April 3, 1944, anterior wounds over a fracture were connected. An unsuccessful effort was made to fix the fracture by multiple screws. Then periosteum over a long middle fragment was stripped and a long plate was applied anteromedially, stabilizing the fracture. Two posteromedial wounds were connected to form a relaxing incision, allowing closure of the operative wound. However, the latter failed to heal completely. The center of the incision opened exposing one inch of plate. There was no evidence of wound sepsis but simply failure of healing due to mechanical factors. At his last plaster change in this Theater in mid-May, the wound was clean but about .75-inch of plate was exposed. Following removal of the metal and several sequestra, in the Zone of Interior, at which time the fracture was firmly united, the wound healed and function of the extremity was resumed.

COMMENT: In retrospect, the fractured tibia might have been adequately stabilized by plating the fibula or treated by encasement traction, thereby avoiding periosteal stripping and the placing of metal at a point where it interfered with closure of soft parts over bone. The anteromedial surface of the tibia is not a good location for the plate if there is any question of wound healing. The wounds in this case determined that the location of the incision was over the site of the metal.

Case 6.—*Diagnosis:* F. C. C. femur, junction M/3 and L/3.

Wounded: September 28, 1944, by small arms fire.

Initial Surgery: October 1, 1944. Time-interval, 60 hours. Extensive excision of devitalized muscle with established sepsis was necessary in the posterolateral thigh through a huge, jagged wound. Vaselined gauze dressing and 1.5 hip spica.

Reparative Surgery: On October 17, 1944 (delayed for tactical reasons), the encasement was removed, a K-wire was inserted in the tibial tubercle and the extremity placed

in the 90–90–90 operative position. The contour and location of the fracture plus the delay in definitive fracture management might have been considered an indication for rigid internal fixation. However, wound exploration revealed *no exposed bone* and extensive periosteal stripping would have been necessary for fixation. Therefore, skeletal traction was selected, using the tibial wire for traction and a supracondylar wire for lift. The huge wound was partially closed with good drainage. A snug pressure dressing was applied.

COMMENT: The disadvantages of internal fixation in compound fractures outweighed the advantages, therefore, it was not employed. To have extensively stripped periosteum would have recompounded the fracture, risking bone sequestration. The result justified the judgment.

Case 7.—*Diagnosis:* F. C. C. of tibia and fibula, left.

Wounded: May 24, 1944, by high explosive shell fragment which penetrated the medial surface of the left leg midthird fracturing both bones.

Initial Surgery: Not recorded but apparently routine.

Reparative Surgery: At reparative surgery, May 26, 1944, several totally loose fragments of a badly comminuted tibia were removed through the compounding wound. The transverse fracture of the fibula was plated through a separate operative approach, thereby stabilizing the fractured tibia in adequate reduction. The operative wound was sutured but muscle and skin loss precluded suture of the compounding wound. It was filled with fine-mesh gauze and an encasement applied for Orr treatment. The sutured wound healed and the medial wound granulated to complete healing before evacuation to the Zone of Interior in mid-July.

The wound remained healed but union of the fracture was delayed (bone loss). Because wound healing had been achieved early, reinforcing bone grafting was carried out as soon as the indication could be determined. The fracture is now solidly united in full length and alignment.

COMMENT: Wound revision as the primary step of reparative surgery of compound fractures revealed totally loose bone fragments. Fibula plating converted for practical purposes the fracture of both bones of the leg into a fracture of only the tibia. The character of the defect of the wound of injury precluded closure. Therefore, the Orr method was employed with good results. The excellent reparative surgery permitted early and complete reconstructive surgery.

Case 8.—*Diagnosis:* F. C. C. of the femur, bilateral.

Wounded: March 26, 1944, 0300 hours, by machine gun bullets perforating each thigh, fracturing each femur about the junction of the middle and lower thirds.

Initial Surgery: March 26, 0930 hours. Time-interval, 6.5 hours. The wounds of entry and exit were incised and the bullet tracks débrided of the devitalized tissue. The wounds of the left thigh were not extensive, but there was severe muscle damage of the right thigh which created a loss of continuity of the vastus lateralis muscle. Considerable muscle was necessarily excised.

Reparative Surgery: On April 9, 1944, three days after admission to the Base Hospital, and after 1,500 cc. of blood replacement, reparative surgery was carried out on both femurs. The right femur was reduced and stabilized by multiple screw fixation, through the compounding wound, enlarged by an incision distally. The size of the defect was reduced by as much closure as possible, which placed soft parts over the metal and most of the exposed bone. The remaining cavity was loosely filled with fine-mesh gauze. In addition, dependent drainage was established through the postero-

lateral plane. The compounding wounds on the left were sutured and dependent drainage was established. Both drains were removed on the eighth postoperative day.

Both extremities were placed in skeletal traction—that on the right to protect the internal fixation, permit early joint motion and provide access to the wounds for necessary dressings—that on the left, for definitive fracture reduction. The sutured portion of the right thigh wound healed and the defect slowly filled with granulations. It was necessary to use two-wire skeletal traction on the left femur but union in excellent reduction was obtained and the wounds healed. A late follow-up observation on March 23, 1945, reveals the fracture firmly united, all wounds healed and about 90 degrees of motion in each knee.

COMMENT: Multiple screw fixation of the right femur produced anatomic reduction and alignment with minimal periosteal stripping. The partial closure covered practically all exposed bone, but it was necessary to resort to a method of loose packing and infrequent dressings to permit granulations to fill the defect. The dependent drainage established on the right was considered important, but that on the left might have been omitted. In fact, the surgeon performing the operation stated that his drain did not reach the fracture site.

Case 9.—*Diagnosis:* F. C. C. humerus with bone loss.

Wounded: October 21, 1944, 1200 hours, by high explosive shell fragment perforating arm and fracturing the humerus.

Initial Surgery: October 21, 1944. Excision of devitalized tissue. Four centimeters of humerus were missing; the brachial artery, median and ulnar nerves were exposed and found intact; the radial nerve was severed. Because of danger of injury to the artery by the sharp fragment ends, a wire loop was used to overcome the 4 cm. gap and hold the fragments in approximation. The wounds were dressed and a Velpeau plaster utilized as transportation splinting.

Reparative Surgery: On October 30, 1944, the fracture site was inspected, the wounds cleaned of blood clots and a few tags of muscle excised. The lateral wound was closed. The medial wound was grafted. A slip of fine-mesh gauze extended through the grafted medial wound to dead space about fracture site. A pressure dressing was applied and a shoulder spica used for immobilization. On November 17, 1944, at change of plaster, the lateral wound was solidly healed, a 75 per cent take of the graft was seen. The fracture site appeared to have sealed-off, and there was no opening to bone.

COMMENT: This case illustrates an excellent use of internal fixation at initial surgery and justifies a policy of permitting the procedure in Forward Hospitals on definite indications usually to protect vessels or nerves. If the wire loop had not been used in the Evacuation Hospital, it would have been placed in the Base to overcome the bone deficit. By closure and graft, plus a partial open wound with fine-mesh gauze for drainage the skin defects were minimized and the compound fracture soon became sealed-off.

Case 10.—*Diagnosis:* F. C. C. right humerus.

Summary: The patient was wounded on April 8, 1944, by a high explosive shell fragment which produced a massive soft-tissue injury of the right arm and a comminuted fracture of the humerus. A radial palsy was present. Initial surgery was the routine. At reparative surgery in the Base, several totally loose bone fragments were removed, producing a one-inch segmental bone defect, which was overcome by the use of a wire loop to hold the major fragments in contact. The radial nerve was visualized intact. The muscles of the arm were sutured over the exposed bone with

fine-mesh gauze drainage from the fracture site and a shoulder spica applied. After a granulating bed had formed, the skin defect was covered by a split-skin graft on May 20, 1944. Complete healing of the compounding wound was obtained and the fracture united prior to evacuation to the Zone of Interior in July. There was partial recovery of radial power.

COMMENT: At reparative surgery, potential sequestra were removed and bony contact predisposing to union was obtained by wire loop internal fixation. Muscle closure over bone obtained the major objective of wound closure. Fine-mesh gauze drainage was used for a few days. Delayed skin grafting completed the reparative surgery.

Case 11.—*Diagnosis:* F. C. C. of tibia and fibula.

Wounded: June 8, 1944, by high explosive shell fragments penetrating the left leg, fracturing the tibia and fibula.

Initial Surgery: Not recorded but presumably routine.

Reparative Surgery: June 17, 1944, four days after admission to Base Hospital, exposure revealed two clean wounds, one anteromedial exposing the fracture site, the other posterolateral. The tibia was stabilized in reduction by multiple screw fixation through the anteromedial incision, which was then sutured after a posteromedial relaxing incision. Drainage was established through the posterolateral injury wound. The sutured wound healed and the two posterior wounds were almost healed, with no sinus formation, when he was evacuated to the Zone of Interior in mid-July.

In the Zone of Interior the fracture united in anatomic alignment and the wounds remained healed. He is now on duty in a General Hospital.

COMMENT: Multiple screw fixation permitted stabilization of the fracture in anatomic reduction without additional periosteal stripping and without excessive intrawound trauma. The relaxing incision permitted the sliding of a skin flap and closure of the anterior wound without tension over the exposed bone, thereby attaining a major objective of reparative surgery of compound fractures.

Case 12.—*Diagnosis:* F. C. C. femur.

Wounded: October 26, 1944, 1200 hours, by high explosive shell fragment, which fractured the left femur in its midthird and produced an extensive soft-tissue wound.

Initial Surgery: October 26, 2200 hours. Time-interval, 10 hours. Excision of devitalized tissue; vaselined gauze dressing and Tobruk splint.

Reparative Surgery: November 1, 1944, six days after wounding, and three days after admission to the Base Hospital, during which time 1,500 cc. of whole blood were given, the femur was stabilized by multiple screw fixation, and the large gaping wound was partially closed. The wound was dressed with fine-mesh gauze and the extremity placed in skeletal traction. November 15, 1944, the sutured wounds were healed. The fracture site had sealed-off so the remaining defect was skin grafted.

COMMENT: Multiple screw fixation stabilized the fracture in anatomic reduction and permitted handling of extremity for subsequent management of the extensive soft-part wound. Partial skin closure reduced the size of the defect. This is an excellent example of reparative surgery of a severe battle compound fracture. Reduction in skeletal traction is difficult to maintain when the surrounding soft tissue loss is extensive.

Case 13.—*Diagnosis:* F. C. C. right tibia lower third.

Summary: The patient was wounded by a fragment following a land-mine explosion which penetrated the anteromedial surface of the right leg, fracturing the tibia. At

initial surgery, the wound of entry was débrided and a foreign body removed. At reparative surgery in the Base Hospital a long posteromedial relaxing incision permitted closure of the compounding wound covering the exposed fracture site. The defect created by the relaxing incision was covered by split-skin graft. Complete wound healing was obtained.

COMMENT: The exposed fracture site was covered with soft-parts facilitating their revascularization, preventing contamination at changes of plaster and providing healthy skin over the bone.

Case 14.—*Diagnosis:* F. C. C. tibia, upper third, right.

Wounded: March 8, 1944, 1745 hours, by high explosive shell fragment which perforated the proximal leg, comminuting the tibia.

Initial surgery: March 8, 1944, 2130 hours. Time-interval, 3.75 hours. The wounds of entry and exit were connected to provide exposure for débridement and arrest of severe hemorrhage from the cancellous bone which required tight packing.

Reparative Surgery: March 16, 1944, the day after admission to the Base Hospital, the fracture site was cleansed, the irregular wound was sutured so as to cover, as best as possible, the exposed bony cortex, tips of denuded fragments remaining exposed were ronguered away, the wound was dressed with fine-mesh gauze and an encasement applied. The patient remained on his side, facilitating dependent drainage. At change of encasement a week later the wound was clean and "dry" and healing of the closed wounds permitted removal of the sutures. The cavity remaining was loosely filled with fine-mesh gauze and an encasement applied. The latter was changed in late April, at which time the wound was clean and partially filled by healthy granulations. No bony cortex was exposed. He was then evacuated to the Zone of Interior.

COMMENT: The partial wound closure covered, protected and aided in preserving the exposed cortical bone and reduced the size of the wound defect. Initial surgery was excellent, so no further excisional surgery was necessary. The character of the defect including the loss of tissue and residual dead space dictated the Orr method of treatment.

Case 15.—*Diagnosis:* (1) F. C. C. left femur, midthird. (2) F. C. C. left tibia, upper third.

Wounded: January 18, 1944, 1500 hours, by high explosive shell fragments penetrating left leg and thigh anteriorly, fracturing the tibia and femur.

Initial Surgery: January 18, 1944: Débridement of all wounds, removal of foreign bodies, application of a 1.5 hip spica.

Early Base Care: January 30, 1944, 12 days after wounding, the wounds were dressed, and femoral skeletal traction instituted, with a boot encasement on the leg and foot. The anterolateral wound compounding the femur was extensive, with muscle loss exposing the femoral fragments for several inches. The fracture of the femur united in good position but there was massive sequestration of portions of the major fragments as well as minor comminuted pieces. The thigh and leg wounds continued to drain with no signs of healing but the patient was not toxemic.

Reparative Surgery: April 6, 1944, 2.5 months after injury, at operation, the sequestra of the femur were removed, and dependent drainage was established in addition to the open anterior wound. At exploration of the tibia, sequestra of indriven cortical bone in the marrow cavity were removed. Both compounding wounds were loosely filled with dry fine-mesh gauze, and a plaster encasement applied. Twelve days later, at a change of encasement, both wounds appeared clean. The patient remained afebrile, and was evacuated to the Zone of Interior about May 1, 1944.

In the Zone of Interior all wounds were healed by September, 1944. Both fractures were sufficiently solid by December to permit weight-bearing.

COMMENT: There was massive sequestration of bone not covered by soft parts, including part of the major fragments. Wound sepsis of both the thigh and leg wounds persisted because of sequestra. Early reparative surgery by wound closure over exposed bone might have prevented the sequestration of the femoral fragments and by adequate wound revision might have prevented the septic tibial wound. Following delayed reparative surgery, the processes were controlled, and wound and fracture healing were achieved.

DISCUSSION.—The plan of management provides indicated surgery in an effort to achieve the best possible anatomic and functional result in the least practicable period of time. The old concept that surgery in a known infected field would result in failure and possible serious complications is ignored. The success attained varies with the accuracy of surgical judgment and the skill of operative technic. Wound revision is conceived as a meticulous completion of excisional surgery to remove tissue that may harbor infection rather than a meddlesome and traumatizing procedure. Clean, well-drained wounds require little or no revision. Fracture management permits the surgeon to "know" the fracture. The adjustment of fragments under direct vision may be an important step towards obtaining maximum fracture reduction.

Internal fixation of battle fractures is admittedly a controversial subject. It is utilized when its advantages outweigh the disadvantages and is employed frequently at the primary operation of reparative surgery in fractures about joints to permit anatomic replacement of articular surfaces, *e.g.*, condyles of femur or humerus; in fractures of long bones deep in muscle tissue, a situation which favors early reattachment of soft parts, *e.g.*, the femoral shaft and upper radius; in those fractures which experience teaches are difficult to hold in reduction by other means, *e.g.*, olecranon, associated massive soft tissue loss (Case 12), and in fractures with segmental bone loss to achieve contact of fragments in an effort to prevent nonunion. It is to be avoided when the disadvantages predominate, *e.g.*, the tibia, where periosteal stripping is hazardous because the overlying skin is not a sufficiently vascular soft part and where metal may interfere with even skin closure. The surgeon who finds many indications for internal fixation in the management of simple fractures will find many indications in battle fractures, but he must ever be mindful of the hazards of the method. He who uses it as a last resort in simple fractures will use it sparingly in battle fractures. An accurate appraisal of the possibilities of stabilizing the fracture by plating or multiple screws is essential. If the fracture remains unfixed after the metal is placed, the procedure is doomed, as motion at the fracture site will produce absorption about the screws. Experience verifies this conception.

When the indications and advantages are not clear-cut, it is preferable to perform wound closure and attempt fracture reduction by manipulation or traction. If these are unsuccessful, a planned open reduction and internal fixation may be carried out later, perhaps after wound healing. The important point is that poor anatomic results are no longer accepted for fear of

lighting-up infection if they can be prevented by surgical measures performed under good principles.

Reparative surgery has established *delayed* closure over fractures as a logical and surgically sound procedure. Wound closure is conceived primarily to salvage the denuded bone, *protect* the exposed fracture site and *prevent* sepsis; secondarily, it attempts to speed wound healing by the surgical approximation of tissues, thereby minimizing the resultant scar. It does so under the conception that a wide open wound is not essential for adequate drainage if excisional surgery is complete and dead space held to a minimum; that drainage is preferably dependent and that it may be adequately provided in many instances by fine-mesh gauze or rubber wicks emerging through sutured wounds or counterincisions. The theoretic objection that drains to fracture sites are conducive to sinus formation has not been substantiated in this experience. Wound healing, while affected by several factors, is a natural cellular growth[15] provided the wound does not contain dead tissue, strangulating ligatures, dead space, *etc.* Wound closure, in an effort to achieve rapid wound healing, is practiced to the extent to which these qualifying factors may be surgically obviated.

Clinically clean cases on admission to the Base Hospital lend themselves to the full program, with anticipated good results. Of even greater importance, a surgical approach is established for the clinically dirty wounds and for wounds with established sepsis, groups which always were the major problems in war surgery. By judicious application of the surgical principles of reparative surgery, *i.e.,* excision of dead tissue, obliteration or dependent drainage of dead space, pressure dressings, adequate reduction and immobilization of fractures and staged closures, these problem cases may be converted into clean cases, reparative procedures instituted and the objectives of the program achieved.

A thesis of this treatise is the restoration (or preservation) of the periosteal blood supply of the cortex of bone to prevent its sequestration. Indeed, the major problem of the management of battle fractures is the denuded cortex of bone which will surely sequestrate unless it is rapidly revascularized. In the presence of sequestrating bone, wound healing and fracture union are retarded or prevented. If all denuded bone in a battle fracture could be excised, wound healing would come easy, but the price in deformity is prohibitive. Therefore, the problem is the restoration of vitality to denuded bone while at the same time obtaining and maintaining fracture reduction projected towards bony union and the functional restoration of the extremity. The principles of reparative surgery of compound fractures are designed to solve that problem.

APPRAISAL OF RESULTS

In a Theater of Operations, statistical results on compound fractures cannot be compiled. End-results are not seen as many cases are evacuated to the Zone of Interior before wound or fracture healing is complete. Multiple

observers in many hospitals compiling tables of results would only confuse the issues. Therefore, conclusions of experienced overseas War Surgeons based upon continuing study and observation must serve to evaluate the over-all program. The consensus of opinion on the reparative program for compound fractures is summarized as follows:

1. Septic patients are few. No deaths, amputations or serious sequelae *resulting from* overzealous reparative surgery have been reported. This refutes the old impression that surgery in an infected field would establish a generalized sepsis.

2. Wound sepsis has been minimized. When it is established following reparative surgery, wound revision is again employed excising or draining the pabulum anticipating staged closure if surgically feasible, rather than await sequestration of the devitalized tissue and risk further local necrosis of living tissues.

3. Fracture reductions are greatly improved as inadequate reduction is not tolerated if it can be improved by nonoperative or operative procedures. Segmental bone deficits forecasting nonunion are rarely accepted.

4. Internal fixation of fractures particularly around joints has restored joint congruity and permitted early joint motion and muscle exercise pointing towards improved functional results.

5. Complete wound healing following suture has been obtained in many cases. In others, the fracture site was rapidly closed-off resulting in, for practical purposes, a simple fracture with skin defects to heal by granulation aided by split-skin grafting. In many cases prolonged drainage from the depths of the wound has been inevitable with any form of treatment, *e.g.*, badly comminuted fractures with many partially detached fragments and with associated dead space. Drainage will persist until the denuded bone has been revitalized or becomes a sequestrum and removed. As sequestration occurs, sinus formation develops and persists. If there is free egress for the drainage, continuing local necrosis is *nil* or at a minimum. Where the sinus is to sequestra that could not be prevented surgically, they must be accepted as a result of the injury. Here, again, the failure of wound healing results from retained dead tissue, the sequestrum, rather than from the invasive action of bacteria *per se*. When the degree of wound healing obtained has not been that anticipated, the result has been attributed to errors in judgment as to what was surgically feasible or to errors in technic. Under the plan of management scar formation, with its effects on future function, has been minimized.

It is regretted that figures are not available on the end-results of fracture and wound healing obtained when metallic internal fixation was used. It is stressed that reduction of the fracture, not the use of internal fixation is the objective. Observation within the Theater and reports from the Zone of Interior indicate that, in a substantial majority, the fractures have nnited and the wounds have healed. Persistent sinus formation, possibly to metal, possibly to sequestra, is anticipated in a certain percentage of cases. If

union of the fracture in good position occurs and the wound heals after removal of the metal and sequestra in the Zone of Interior, as is anticipated in this group, the result will be considered satisfactory. Any nonunions should be evaluated against the probabilities of nonunion had internal fixation not been used. The over-all results must be evaluated in the light of the problem at hand for which the surgeon chooses internal fixation as a part of reparative surgery. Through arrangements approved by the Surgeon-General and the Surgeon, Mediterranean Theater of Operations, a detailed follow-up study on this group of cases is under way, and will be the subject of a later report.

A comparative appraisal of the reparative program with methods of management previously employed is deemed unessential. It is sufficient that veteran war surgeons who have observed and studied the development and results (as seen in this Theater) of reparative surgery of compound fractures are satisfied that the objectives of the program have been "surrounded and isolated" if not "taken." Further experience with continuing reëvaluation of results will undoubtedly produce modifications in the surgical management of these war wounded. Blood and penicillin, the surgical adjuncts, have contributed greatly, possibly their maximum, to the success of the program. However, improved results may be anticipated with perfection of surgery for which there is no substitute in the management of the wounds of war.

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THE MANAGEMENT OF INTRATHORACIC AND THORACO-ABDOMINAL WOUNDS IN THE COMBAT ZONE

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Those casualties with the most severe wounds of the chest die on the battlefield. With available and intelligent care, most of the remainder may live. Much has been learned concerning management of chest wounds since American forces landed in North Africa in 1942. The Fifth Army campaign in Italy has provided much opportunity for study and improvement. Experience has led to the salvaging of an increasing number of lives. It is the purpose of this paper to discuss the care of chest wounds in the combat zone only. This includes all management from the time first aid is rendered, until after primary definitive surgery has been performed in a field or evacuation hospital, and the patient is ready for evacuation to a base hospital. Statistical data and case reports are used to support important policies and procedures advocated. Personal opinions are based upon the writer's experience as head of a thoracic surgery team in an evacuation hospital in England and North Africa, as surgical consultant to the Second Corps in Tunisia and Sicily, and as surgical consultant to the Fifth Army in Italy. As surgical consultant the writer has had the privilege of doing surgery in some, and of observing the surgery done in all forward hospital installations in Tunisia, Sicily, and Italy. Case reports on all major thoracic wounds admitted to the Second Corps hospitals in Northern Tunisia and Sicily have been studied and case reports on all battle casualty deaths in the Fifth Army hospitals since January 1, 1944, have been available. Frequent visits to base hospitals and thoracic surgery centers to which casualties have been evacuated, and suggestions from the base surgeons have been most valuable. The development of our present methods of management of chest wounds has been accomplished under the able supervision of Colonel Edward D. Churchill, consulting surgeon, M. T. O. U. S. A.

HOSPITALIZATION

In the Fifth Army, the primary definitive surgery of chest wounds is done either in field or evacuation hospitals. Active divisions are supported by a field hospital unit placed immediately adjacent to the division clearing station. This unit is augmented by two to eight general surgical teams and one shock team from an auxiliary surgical group. The clearing station is usually situated four to ten miles behind the front line. All casualties from the infantry regiments are cleared through this station. It is the triage or sorting point. First-priority cases are carried by litter to the adjacent field hospital, others are evacuated by ambulance to evacuation hospitals, usually situated four to ten miles further back (Diagram). Evacuation hospitals also receive first-priority cases from aid stations of Army units and units which may be closer to the evacuation hospital than to the clearing station.

Field hospitals are prepared to do intrathoracic surgery and to hold patients

postoperatively 10 to 14 days, or longer, as indicated. Roentgenologic facilities, suction machines, bronchoscopes, thoracic surgery instruments, positive pressure anesthesia machines of the same sort as found in evacuation hospitals are now available in these forward units. Blood is supplied from the Base in adequate quantity. Additional nurses augment the nursing staff of the hospital when needed.

Personnel problems have required much study and attention. Each evacuation hospital is supposed to have a thoracic surgeon or general surgeon experienced in traumatic surgery of the chest. Now, each evacuation hospital is so staffed, but this was not true in the beginning. There were not enough thoracic surgeons available to do all the chest surgery in field hospitals. General surgeons had to learn the surgical technic peculiar to intrathoracic surgery. They had especially to learn sound principles of pre- and postoperative management of wounds of the chest. A number of factors contributed to the education of these general surgeons. Their actual experience with thoracic wounds which demanded emergency surgery was most important. In many instances it was possible to place a thoracic surgeon or a thoracic surgical team in a field hospital unit. At times this team attempted to care for most of the chest wounds admitted. Other times, the thoracic surgeon acted as consultant to the general surgeons in their management of chest wounds. In some instances he acted as assistant surgeon at the operation and in other instances he was assisted by the general surgeon. The formally trained thoracic surgeons have contributed much in this educational program. However, they have, themselves, required much education. Some were completely inexperienced in abdominal surgery or had not done abdominal surgery for a number of years. They required the assistance of a good general surgeon to handle properly thoraco-abdominal wounds, which comprise a large part of the first-priority or nontransportable chest cases. The formal training of thoracic surgeons was peculiarly limited to elective surgery of thoracic disease and, except as the basic principles of this experience were pertinent, they were totally unfamiliar with the clinical management of thoracic injury. In the future, if traumatic surgery of the chest is to be well done, in civil life or in time of war, all general surgeons must have training in thoracic surgery. Likewise, if there are to be specialists in thoracic surgery, they must be good general surgeons. It was more than two years after Pearl Harbor before enough general surgeons were trained to care adequately for patients with wounds of the chest in this theater of operations.

Dissemination of knowledge gained by those with early experience, frequent group discussions, medical conferences of the Fifth Army, reports from Base surgeons, suggestions from consultants have all contributed to the improvement in forward thoracic surgery.

A similar program of education has been necessary for the anesthetists. Many lacked training and experience in endotracheal anesthesia for chest surgery. With the coöperation of fully trained and experienced anesthetists and chest surgeons, a large number have been trained to pass endotracheal

tubes, to properly expand the lungs by positive pressure, and to do bronchoscopic aspiration of the trachea and large bronchi. Proper training and experience on the part of the anesthetist is just as important as the training and experience of the surgeon in the management of wounds of the chest.

TRIAGE

Early experience demonstrated that some patients were definitely not transportable beyond the division clearing station because of the thoracic or thoraco-abdominal wounds. Later experience has shown that many lives can be saved if even more than the absolutely nontransportable patients are given the benefit of surgery in the field hospital unit which is set-up immediately adjacent to the division clearing station. A study of all battle casualty deaths in evacuation hospitals in Fifth Army in one of the early months of the campaign[1] disclosed that approximately 36 per cent of those dying might have lived had they had surgery in a field hospital. More than one-third of these, or approximately 15 per cent of the entire group, had sucking chest wounds, thoraco-abdominal wounds, or wounds of the chest accompanied by shock or dyspnea. (Case 1 is illustrative.) Corrective action was taken and a larger percentage of the wounded now have surgery in the field hospital unit.

It is now considered desirable that the following types of chest cases be regarded as first-priority and be transferred to the nearest hospital installation for surgery. (In the case of active divisions, this nearest hospital should be a field hospital unit, staffed with auxiliary surgical group teams and situated in close proximity to the division clearing station.)

1. All of those in shock or who have been in shock.
2. All of those with continuing hemorrhage.
3. All sucking chest wounds.
4. Chest wounds in which there is any degree of respiratory difficulty or dyspnea.
5. All thoraco-abdominal wounds.

FIRST AID MANAGEMENT OF WOUNDS OF THE CHEST

The first aid management of wounds of the chest is begun by the first member of the medical department to see the patient. This is usually the aid man. The first step is the application of an occlusive dressing to the wound. It has been pointed out[2] that every chest wound should be dressed as though it were a sucking wound, for many not sucking at the time the dressing is applied may begin to suck when the patient changes position or moves an arm. The dressing should consist of a layer of vaselined gauze (if available) next to the skin and a gauze pad, strapped firmly in place with overlapping layers of adhesive. It may be necessary in large open wounds to anchor the gauze dressing to the skin, wide of the wound, with a few sutures. Usually gauze and adhesive properly applied will close the wound tightly enough. Emergency closure of the wound by suture is condemned. Some patients who have had such closures have developed tension

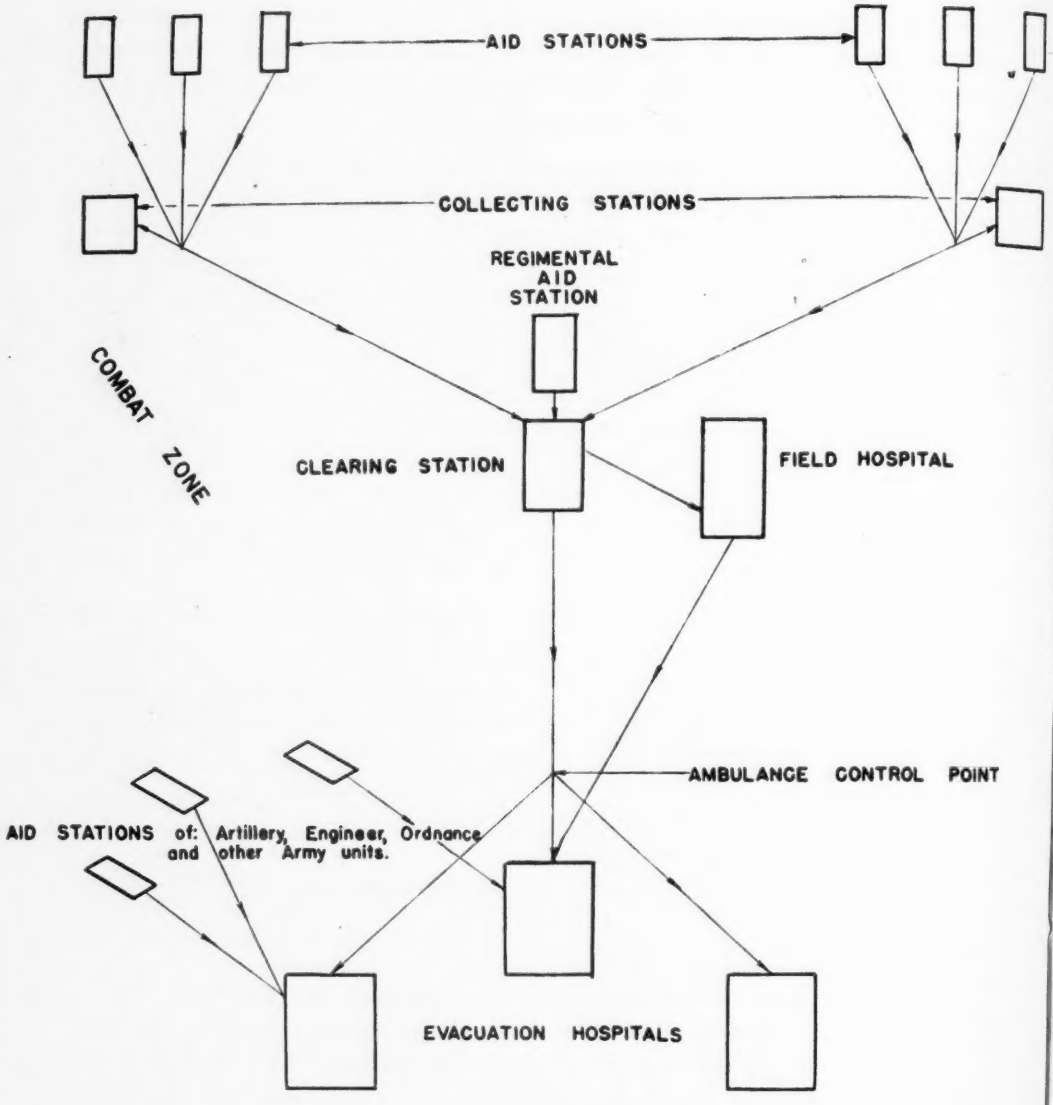

FIG. 1.—Diagram showing line of evacuation of battle casualties.

pneumothorax and died on the way to, or shortly after reaching a hospital. In others, extensive subcutaneous emphysema has resulted. In times of stress in a hospital, a sutured wound may receive no further attention under the assumption that débridement has been done and later on the wound becomes infected and breaks open.

A large pneumothorax or a tension pneumothorax may demand attention in the aid or collecting station. Tension pneumothorax *per se* is rarely seen. A large-bore needle or a small catheter may be inserted in the second interspace anteriorly and fitted with a flutter valve made from a condom, old rubber glove or Penrose drain tubing.

Shock must also be treated. It has not been practical to use whole blood in aid or collecting stations. Its use in the clearing stations is not desirable when the patient can be immediately transferred to a field hospital. The minimum amount of plasma necessary for resuscitation should be administered and further replacement therapy delayed until the wounded man reaches a hospital.

PREOPERATIVE MANAGEMENT OF WOUNDS OF THE CHEST IN HOSPITAL INSTALLATIONS

When a patient with a chest wound is admitted to the hospital an immediate, rapid examination must be made to determine (1) the blood pressure and pulse findings; (2) whether the wound is properly dressed and not sucking; (3) the probable extent of blood loss; (4) the presence or absence of large amounts of blood or air in the pleural cavity; (5) the presence or absence of cardiac tamponade; (6) the position of the mediastinum; (7) presence or absence of paradoxical respiration, or of a painful chest wall wound hindering adequate respiratory movement; and (8) presence or absence of blood, mucus, *etc.*, in the tracheobronchial tree.

As the rapid appraisal is made, indicated resuscitative measures are promptly instituted. The wound dressing is made adequate. The litter is left level, or the foot is elevated. Occasionally the dyspneic patient whose blood pressure is above 80 or 90 and who is not comatose will be more comfortable if the head and chest are elevated. With a blood pressure below 80 or a comatose patient the litter is best left level or placed in shock position. Blood replacement, autotransfusion, aspiration of hemothoraces and pneumothoraces, tracheal aspiration, intercostal nerve block, and oxygen therapy are rapidly accomplished when indicated. These measures will be discussed separately.

Blood replacement therapy is immediately started. Low titer Group-O blood* is used if shock is extreme, otherwise plasma is used until the patient can be grouped and cross-matched. Lalich[3] has suggested a simple classification of battle wound shock to be used in estimating the amount of blood necessary and the speed with which it should be administered. It is most important in severe shock to administer blood rapidly until the pressure approximates normal, then slowly till the proper amount has been given in

preparation for surgery. Beecher and Burnett[4] have demonstrated the importance of the timing in replacement therapy. In their series of 37 carefully studied cases in severe shock (the worst of 2,800 battle casualties) the average time for preparation for surgery was two hours and 21 minutes. They feel that when the patient cannot have surgery at the optimum time only sufficient blood should be given to raise the systolic blood pressure to about 80 mm. Hg. and to maintain it there provided the patient is warm and of good color. More blood is then given immediately preceding and during surgery. The use of whole blood, rather than plasma, in replacement therapy is most important in chest wounds where oxygen want is often present from factors other than hemorrhage. It has been thought that the individual with a chest wound is more prone to develop pulmonary edema, from the infusion of blood or blood substitutes. Caution must be exercised to avoid giving blood rapidly after the systolic blood pressure exceeds 70 or 80 mm. Hg. As a rule, a little less blood is given when wounds involve the chest. However, the experience of most doctors in forward hospitals seems to indicate that an adequate amount of whole blood may be given, if plasma has not been given in excess, and if the tracheobronchial tree is kept relatively free of blood and mucus.

Autotransfusion of blood aspirated from the chest has been most useful in the resuscitation of those with chest wounds in which much hemorrhage into the pleura has occurred. As much as 2,100 cc. of blood has been aspirated from one or both pleural cavities and rapidly autotransfused. Most have avoided autotransfusion if more than 24 to 36 hours have elapsed after wounding. The blood is always filtered, and may or may not be citrated. Sanger[5] uses a transfusion vacuum bottle containing citrate, to aspirate acute hemothoraces, and blood so obtained may be immediately administered, using the customary recipients tubing set which has a stainless steel mesh filter incorporated. He has stressed that the blood should not be given, however, if there is any question of contamination by stomach or bowel content as there may be in a thoraco-abdominal wound. In case of doubt, the blood is held until operation proves or disproves the point in question. With low titer Group-O blood available for emergencies, this precaution is certainly indicated.

Aspiration of hemothorax and pneumothorax should be carried out as soon as possible in the patients with dyspnea or severe shock. The rapid restoration of the normal position of the mediastinum, and reëxpansion of the lung accomplished by evacuating the pleura of blood and air are most desirable and parallel or exceed the importance of blood replacement. Intercostal nerve block may be accomplished at the same time local anesthesia is used in preparation for aspiration. Blood or air is withdrawn until the patient begins to complain of a sensation of tightness or pain in the chest. In the first 24 hours after wounding from 1,000 to 2,000 cc. of blood (or of air) may be withdrawn at one time without distressing the patient. There

* Group-O blood with anti-A and anti-B agglutinogens in titer less than 1–64.

has been no evidence, in our experience with hundreds of cases, that early aspiration prolongs or brings about a recurrence of hemorrhage. Air replacement is not practiced and is condemned for the following reasons: (a) It is not necessary to arrest or prevent hemorrhage; (b) it is desirable to evacuate the pleura of both blood and air to restore pulmonary function; and (c) if infection develops, collapse of the upper lobe incidental to the pneumothorax leads to total empyema rather than basal. In short, reëxpansion of the lung is the effect desired.

In those cases in which intrathoracic *hemorrhage* is continuing, the patient may require immediate aspiration to relieve respiratory embarrassment from the large hemothorax, and it may be necessary to repeat the aspiration within one to three hours. (See discussion of continuing hemorrhage below.)

The technic of thoracentesis varies in different hands. Local anesthesia should be used. If the patient has had intercostal nerve block, local infiltration of the skin at the site of puncture is all that is needed. A 17-gage needle should be used. It is connected with a vacuum bottle or with a syringe fitted with a three-way valve, so that air is not allowed to enter the chest during aspiration. In the absence of these, a short piece of rubber tubing with appropriate adaptors may be substituted, having an assistant clamp the tubing while the syringe is removed and emptied. The blood should always be aseptically collected so that it may be used for autotransfusion.

If a bronchial fistula is present, means must be provided for continuous evacuation of the air which escapes into the pleural cavity. This is best accomplished by inserting a No. 14 F. soft rubber catheter in the second interspace in the midclavicular line and connecting it with a water seal bottle.

Tracheobronchial Aspiration.—Tracheobronchial obstruction from blood and mucus is always encountered in varying degrees in patients with intrathoracic wounds. In some patients, tracheobronchial aspiration must be done as an emergency procedure before anything else is undertaken. In most cases, coughing will be sufficiently effective to clear the obstruction after intercostal nerve block has been performed. Encouraging the patient to cough and assisting him by supporting the injured side of his chest are helpful. In more seriously wounded patients and in patients in coma other measures are necessary. Catheter aspiration of the trachea, without topical anesthesia, as described by Haight,[6] may remove enough of the obstructing material to relieve the patient. Many anesthetists, surgeons, and shock officers have mastered the simple technic of this procedure. In some installations, nurses and enlisted men have been trained to carry it out in emergencies. The patient's chin should be down and the tongue pulled out. A urethral catheter with an additional hole at the proximal end is inserted through the nose into the pharynx; as the patient inspires, it is gently pushed through the open glottis. Much mucus and blood may be aspirated through the catheter, and perhaps more is evacuated by the coughing stimulated by the procedure.

The procedure is usually completed in 30 seconds to two minutes. How-

ever, in exceptional instances, it has been necessary to leave the catheter in place for a number of hours to maintain an adequate air-way.

In some instances, bronchoscopic aspiration must be used to more completely clear the tracheobronchial tree. With continuing hemorrhage into the tracheobronchial tree it may be mandatory. Shefts[7] found it necessary in one instance to pack a main stem bronchus to control hemorrhage which developed while a patient was being anesthetized. A thoracotomy was performed, the bleeding point controlled, and the pack then removed. In this instance, bronchoscopy was clearly an emergency life-saving measure. It is sometimes desirable to administer oxygen through the bronchoscope while doing the bronchoscopy.

Intercostal Nerve Block.—The relief of pain by intercostal nerve block with novocaine is of major importance in the early management of painful chest wounds. Where pain is seriously hindering respiratory movements, or preventing effective expulsion of blood and mucus in the tracheobronchial tree by cough, it should be performed immediately. Numerous reports and papers[8, 9, 10] from the Mediterranean Theater of Operations, have emphasized the importance of this measure in the various phases of the management of chest wounds. The effects derived from the relief of pain, permitting effective cough and deeper respiratory movements, are often dramatic. Dyspnea, cyanosis, paradoxical respiration, and tracheobronchial obstruction from blood, mucus, *etc.*, often may be relieved, or very favorably influenced, by this simple measure. The intercostal nerves, two segments above and below the lesion, are each injected with four to six cubic centimeters of 1 per cent novocaine.

Morphine.—Many patients have had enough or more than enough morphine administered prior to admission to an army hospital. However, some have had none, and in these the intravenous administration of $\frac{1}{6}$ gr. of morphine plus $\frac{1}{100}$ gr. of atropine is desirable. When indicated, this should precede intercostal nerve block and thoracentesis.

Oxygen Therapy.—The administration of oxygen by nasopharyngeal catheter or B. L. B. mask or anesthetic machine is indicated almost routinely in severe wounds of the chest. It must not be used to the exclusion of other more important preoperative measures outlined above. To give oxygen to a patient with an obstructed air-way is a futile gesture. Positive pressure oxygen has been used in some cases with excessive moisture (perhaps pulmonary edema) which has not been controlled by other measures.

Completion of Preoperative Diagnosis.—All of the above measures must be instituted rapidly and during their execution, the preoperative diagnosis is established. Points to be determined during this period include: (1) What is the trend of the pulse and blood pressure? (2) Is serious bleeding continuing or recurring as shock is controlled? (3) Is there a wound of the diaphragm? (4) Is there a large bronchial fistula? (5) Is there a wound of the esophagus? (6) Are there indriven bone fragments? (7) Are there retained foreign bodies? (8) What is the position of retained foreign

bodies? (9) What is the extent of wounds in other parts of the body, particularly those of the abdomen, spine, and skull?

Roentgenologic Study is essential in the determination of many of these points, but must be delayed until movement to the Roentgenologic tent will not endanger the patient. The infusion of blood is usually continued while the study is being made. Radiographs of the chest in two planes should *always* be made. Occasionally, fluoroscopic study is also desirable.

Decision as to Optimum Time for Surgery.—There has been some difference of opinion as to the optimum time for surgery in most wounds of the chest. The agreement is fairly general that there is not the same necessity for haste as in abdominal wounds. However, there is a group of wounds of the chest in which prompt, early surgery must be undertaken to save life. Thoraco-abdominal wounds with continuing hemorrhage from the spleen, liver, kidney, *etc.*, fall in this group. Those few cases with large bronchopleural fistulae, or continuing intrathoracic hemorrhage, demand early, daring surgery. In such wounds, surgery often must be done before resuscitation from shock is complete. Surgery should never be postponed longer than to complete resuscitation in any thoraco-abdominal wound.

Some surgeons feel that patients with thoracic wounds may advantageously be held a number of hours after the blood pressure and pulse are stabilized. It is granted that before surgery is done, all cases must have the anatomic position and function of the thoracic organs restored to as nearly normal as is possible by conservative means. It goes without saying, that the patient must have an effective circulating blood volume. However, it is the writer's opinion that proper preoperative preparation or "stabilization" of the patient with a chest wound is attained by execution of indicated therapy and that arbitrarily delaying surgery a number of hours is to be condemned.

Priority of Chest Surgery in Multiple Wounds.—Experience repeatedly has taught the wisdom of giving the chest wound first-priority in surgical management of multiple wounds. If this is not done, the patient is handicapped during the other procedures by incompetent respiratory function. Defects in the pleura, whether they be through the diaphragm or the chest wall, should be securely closed before other surgery is undertaken. (Excepting those in which transdiaphragmatic surgery is done.) The pleura should be evacuated of blood and air as completely as practical. The tracheobronchial tree should be free of blood and mucus. Failure to follow these principles has resulted in catastrophe (Case 2). Hemorrhage elsewhere constitutes one of the few exceptions. This subject will be discussed further under thoraco-abdominal wounds.

Summary of Preoperative Care.—The most important part of the management of a chest wound is the preoperative care. Prompt and proper aspiration of hemopneumothoraces, blood replacement therapy, tracheobronchial aspiration, intercostal nerve block, oxygen therapy, and proper administration of morphine and atropine save many lives, help avoid unnecessary surgery, and

render safer whatever surgery is done. All of these measures, when indicated, should be completed prior to surgery.

OPERATIVE MANAGEMENT OF WOUNDS OF THE CHEST

Replacement Therapy During Operation.—Proper provision must be made for the intravenous administration of blood during all thoracotomies. Frequently a canula has been placed in an ankle vein during the preoperative period. If not, it should be placed before the operation is started. Through it blood may be given rapidly and the canula is not likely to become displaced. In the most serious cases the transfusion of blood is continuous throughout the preoperative, operative and immediate postoperative periods.

Anesthesia.—Endotracheal oxygen-ether is the anesthesia of choice for operations upon penetrating and perforating wounds of the chest. It should be administered through a machine providing CO_2 absorption and permitting the use of positive pressure when needed. All such wounds will suck at the time of débridement, if the débridement is complete. Positive pressure is desirable to aid in maintaining or reëstablishing complete expansion of the lung. With an endotracheal tube in place, the tracheobronchial tree may be kept relatively free of blood and mucus during the operation.

Position on the Operating Table.—The position of the wound itself, particularly where only chest wall débridement is to be done, must influence the choice of position. Patients verging on shock, or in shock, should be kept in a head down position. This same position is desirable, whenever lung tissue has been damaged or is to be cut across, on the assumption that the likelihood of air embolism is diminished. When a posterolateral thoracotomy is to be done, the patient is placed on the sound side, with a blanket roll under the lower chest and loin, the under thigh and leg flexed and the top thigh and leg extended with the foot tied to the end of the table. Blankets or sand bags may be used to support the pelvis and the anterior chest. A broad adhesive strap from one side of the table over the upper hip to the other side of the table may be helpful.

Choice of Operative Procedure.—The extent of the operative procedure indicated is usually determined before the operation is started. Findings at operation may modify or change the plan. Three general types of operative procedures may be defined: (1) *Wound débridement limited to the chest wall.* In which surgery is limited to wound débridement, without inspection of or surgical procedure on the thoracic viscera. It includes aspiration of blood from the pleural cavity by insertion of a catheter through the defect in the pleura, irrigation, instillation of penicillin and occlusion of the pleural opening by suture of muscle and fascial planes. (2) *Thoracotomy through the wound.* In which débridement of the chest wall wound is done and inspection of, or surgical procedure upon, the thoracic viscera is accomplished through the wound or an extension thereof. (3) *Thoracotomy separate from the wound.* In which the thoracotomy incision is made at a site of election separate from the wound. The indications for and the technic of these different

procedures will be dealt with in the discussion of the various types of wounds.

Simple perforating and penetrating wounds of the chest comprise the vast majority of thoracic wounds. Excluding the thoraco-abdominal wounds, in the 1,210 cases with chest wounds reported by Sanger,[5] thoracotomy through the wound and separate from the wound were done in only 10 per cent. In other words, with proper pre- and postoperative care, 90 per cent of chest wounds require only *wound débridement limited to the chest wall.* This should consist of thorough excision of the wound tract down to the pleural opening. Loose rib fragments may be removed and contaminated bone ends freshened. Care is exercised to avoid enlarging the opening in the pleura. Some air nearly always enters the pleural cavity. An attempt is made to minimize this by maintaining positive pressure while the pleura is open. A catheter, inserted in the small pleural opening and connected with a suction machine, is used to evacuate any blood or air from the pleura. After the chest wall wound excision is completed, muscle and fascia layers are approximated over the pleural opening with interrupted silk or cotton sutures. The catheter is withdrawn as the stitch completing closure is tied. No attempt is made to suture the pleura itself. The skin usually is not sutured. It is well to aspirate by needle any residual pleural air at the close of operation.

Betts[11] has recently practiced irrigating the pleura in these simple perforating and penetrating wounds of the chest. Three hundred to 500 cc. of physiologic salt solution are injected through the catheter and then withdrawn by suction. This is repeated until the fluid returns clear, then 25,000 units of penicillin in 25 cc. of physiologic salt solution are injected through the catheter. His results would indicate that fewer postoperative aspirations are required when this has been done. Follow-up data on these cases is not sufficient to warrant final evaluation of this procedure. However, the more thorough evacuation of blood from the pleura should reduce the incidence of late clotted hemothoraces requiring decortication.

Sucking wounds or large chest wall defects should have very thorough débridement. Thorough washing of the pleura with physiologic salt solution and the installation of penicillin are of more importance than in simple penetrating or perforating wounds. Insertion of an intercostal catheter for water-seal drainage may be desirable if oozing or exudation is likely to continue from the lung or other intrathoracic structures. This catheter is usually best placed in the seventh interspace in the posterior axillary line, and the Malecot type catheter is preferred. In most instances, however, these wounds may be closed without drainage after irrigation of the pleura.

In these large chest wall defects it may be necessary to undermine muscle bundles bordering the wound or to swing in a pedicled muscle graft to close the defect. The use of interrupted sutures of fine cotton or silk has been found preferable to catgut in the closure of these wounds. Every effort is made to completely expand the lung at the time of closure of the wound. With positive pressure the lung is inflated out *to the chest wall* and a small catheter providing suction is left in the wound until the final occluding stitch is tied.

If a posterolateral intercostal catheter has been placed it may be left clamped off for three or four hours following surgery if one can be certain that expansion of the lung is being maintained. Some prefer to insert, in addition, a small catheter in the second interspace anteriorly and immediately connect this with a water-seal bottle. The local penicillin is not drained off until the posterolateral catheter is connected with the water-seal and unclamped three or four hours later. The anterior catheter should be removed in 12 to 24 hours unless a bronchial fistula is persisting. The posterolateral catheter should be removed in 48 hours.

Aspiration of the tracheobronchial tree by a long catheter passed through the endotracheal tube is accomplished as indicated during operation, always prior to changing the position of the patient, or expanding the lung under positive pressure, and at the close of the operation. Some feel it is important to bronchoscope every patient with a thoracic wound at the close of the operation. Aspiration of the main stem and lobe bronchi is more completely accomplished through the bronchoscope and the patient will be less likely to develop pulmonary complications.

Indriven Rib Fragments.—If rib fragments of any size have been driven inward, they should be removed or elevated at the time surgery of the chest wall is done. Pain and increased pulse rate often persist until this is done. Failure to elevate or remove large fragments protruding into the periphery of the lung has resulted in lung abscess. In some instances, small fragments or spicules of rib will be carried into the lung along the tract of the missile. These have been classed with other small intrapulmonary foreign bodies and have not been removed unless the chest has been opened for some other indication.

Wounds of the lung rarely constitute an indication for thoracotomy. A few cases have been encountered in which one or more lobes of the lung have been partially transected. These required closure with interrupted silk or cotton sutures. Lobectomy is rarely necessary. Partial lobectomy has been done in a few cases, and has usually consisted of nothing more than excision of a devitalized and partially separated tag of lung. The reparative power of the lung seems very great and excision of any lung tissue is rarely justifiable. Some difference of opinion exists as to what should be done with small wounds of the lung if the chest is opened for some other indication. Some surgeons suture the visceral pleura over every wound of the lung which is accessible, others ignore these wounds unless air or blood is escaping. A suture of the visceral pleura seems more desirable, unless it involves enlarging the incision or unduly prolonging the operation.

If a bronchopleural fistula exists it must either be closed by suture or an intercostal catheter inserted for water-seal aspiration of the escaping air. The smallest ones will usually close spontaneously under water-seal drainage within 24 hours. However, even these are best closed by suture, if this can be accomplished through the existing wound or incision.

Large Pleural Foreign Bodies.—Large foreign bodies which lodge in the

pleura usually produce a wound of the chest wall of such size that slight enlargement of this wound will permit removal of the foreign body. If the foreign body is of good size (2 cm., or more, in diameter) it should be removed even though this necessitates a thoracotomy.

Intrapulmonary foreign bodies are rarely removed in forward hospitals, except in those cases where thoracotomy is done for some other indication. When the chest is open, accessible foreign bodies should always be removed. Very large foreign bodies which have produced extensive lung damage should be removed at the time of primary surgery. Failure to do this has resulted in rapidly developing empyema and fatalities.

Esophageal Wounds.—A wound of the esophagus is an indication for thoracotomy. Many times it is difficult to make the diagnosis. Whenever it seems likely that such a wound exists, exploratory thoracotomy should be done; unless there are definite contraindications. In some of these wounds, or suspected wounds, the foreign body lodges in the mediastinum. In others it traverses the mediastinum and a bilateral chest wound complicates the problem. Judicious intervention, wise selection of approach and meticulous attention to all details of chest management will eliminate some fatalities.

Continuing intrathoracic hemorrhage is one of the rarer conditions encountered in forward hospitals. The term as used here applies to those cases in which bleeding imperils life. Diagnosis of continuing hemorrhage may be based upon the following criteria: (1) General evidences of exsanguination with only partial or no response to blood transfusion; (2) rapid reaccumulation of blood within the pleural cavity after aspiration; (3) massive clotted hemothorax with a wound suggesting the possibility of laceration of a large blood vessel; and (4) continuing escape of fresh blood from the wound. The diagnosis must be promptly made and emergency surgery performed. If the blood aspirated from the pleura is autotransfused, and other resuscitative measures promptly executed, early surgery will save the lives of most of these cases who reach the hospital alive (Case 3).

It must be constantly borne in mind that such cases occur but are extremely rare. In the vast majority of cases with intrapleural bleeding, conservative measures suffice. It is not uncommon to aspirate 700 to 1,200 cc. of blood from the chest in patients who do not have continuing hemorrhage of a degree demanding emergency surgery.

The source of the hemorrhage may be found in the chest wall and if one can be certain that bleeding is not continuing elsewhere, thoracotomy is not indicated. Continuing hemorrhage from the lung itself is extremely rare, although many wounds of the lung when exposed at operation do show slight bleeding. In many instances slight enlargement of the wound will permit the necessary exploration and intrathoracic procedures. If a large incision is necessary, it is best to make it separate from the wound and at the site of election. Large sucking wounds frequently break down in the postoperative period and if this wound forms a part of the incision, the

whole incision may dehisce, hence the advisability of a separate incision (Case 4).

A posterolateral thoracotomy through the sixth or seventh interspace or rib bed is the usual elective site for intrathoracic surgery (this does not apply to thoraco-abdominal wounds). In rare instances an anterior approach is desirable. All the procedures recommended above relative to replacement therapy, aspiration of the tracheobronchial tree, expansion of the lung at the close of operation apply, of course, to all thoracotomies. Reinjection of intercostal nerves with novocaine or crushing of the nerves immediately below and above the wound is recommended.

Large Bronchopleural Fistula.—A certain percentage of those with wounds of the chest have a large pneumothorax with complete collapse of the lung. The pneumothorax may or may not be under tension. Conservative management is always tried first. As described above, a small catheter is placed in the second interspace anteriorly and connected with a water-seal bottle. If expansion of the lung does not begin to take place within six to eight hours, or if during this period the patient tends to lose ground, rather than improve, a thoracotomy is indicated. Unquestionably, many die with large bronchopleural fistulae before or just after reaching a hospital. Prompt, bold surgical attention will save some of the few who reach the hospital alive. Sanger[5] has reported two cases of suture of the right main stem bronchus. One of these survived, the other died 72 hours after operation of concomitant wounds including a spinal cord injury.

Wounds of the Trachea.—A few cases with wounds of the cervical trachea have been complicated by sucking wounds extending from the apex of the pleural cavity into the neck. Tracheotomy, débridement, and proper closure of the sucking wound, have resulted successfully in most of these cases which have reached the hospital alive. Wounds of the cervical trachea not complicated by sucking chest wounds have occasionally been managed by primary suture. This, of course, is not advisable if there is much of a defect in the tracheal wall. Wounds of the intrathoracic trachea with tracheopleural fistulae have not been reported.

Large clotted hemothoraces have been mentioned under continuing hemorrhage. Massive clotted hemothorax occurs most frequently as a result of profuse hemorrhage. If hemorrhage has stopped, all preoperative measures should be completed, remembering that emergency surgery may be indicated at any moment with a recurrence of hemorrhage. Thoracotomy is indicated in these large clotted hemothoraces for two reasons: (1) To prevent recurrent and perhaps immediately fatal hemorrhage by securing adequate hemostasis; and (2) to evacuate the large mass of clotted blood from the pleura and secure rapid reëxpansion of the lung.

Cardiac Wounds.—It is a relatively rare event for a patient with a wound of the heart to reach the hospital. Only one case of a wound of the heart with cardiac tamponade has come to the writer's attention.* Lt. Col. C. B. Carter cared for this patient. The pericardium was aspirated of 500

cc. of blood and pericardiotomy was then done. A small wound of the right ventricle was successfully sutured. The patient survived the operation but died 12 to 24 hours later of other wounds, including transection of the spinal cord. There was no reaccumulation of blood in the pericardium.

Tangential wounds or abrasions of the myocardium have been observed at thoracotomy in several cases. Some of these have survived with no apparent symptoms arising from the cardiac wound. These cases may show changes in the electrocardiographic tracings but few have had clinical evidence of disturbance of the conducting system.

Wounds of the pericardium and intrapericardial foreign bodies are occasionally encountered. Most seen have been dealt with through a thoracotomy incision. The pericardium is left open sufficiently to permit drainage into the pleura. Pericardiotomy is occasionally indicated for intrapericardial foreign body.

OPERATIVE MANAGEMENT OF THORACO-ABDOMINAL WOUNDS

Thoraco-abdominal Wounds.—This includes all those cases in which the diaphragm is traversed by a missile. Left and right thoraco-abdominal wounds will be discussed separately.

Left thoraco-abdominal wounds comprise a very interesting and serious group. Failure to recognize such wounds has resulted in fatalities (Case 5). The possibility of the missile having traversed the diaphragm must be considered in every chest wound and abdominal wound. Exploratory thoracotomy may be indicated as a diagnostic measure. In many instances, slight enlargement of the débrided wound may permit exploration sufficient to determine the presence or absence of a wound of the diaphragm (Case 6). When a thoracotomy through a large incision is necessary, it is best to make this incision separate from the wound. However, in some the wound will be in the site of elective incision and thoracotomy through the wound is, of necessity, the selected procedure. Most surgeons familiar with thoracic surgery prefer the thoracic approach to all thoraco-abdominal wounds even though celiotomy must be done in addition. Through the open chest, the diaphragmatic wound is enlarged to permit examination and repair of accessible abdominal structures. In the great majority of instances all necessary abdominal procedures can be carried out through the thoracotomy incision. Splenectomy, repair of the stomach, mobilization of the splenic flexure are much more easily accomplished through this approach, than by celiotomy. Almost the entire small intestine, the transverse and descending colon, and the kidney are usually accessible. Wounds of the retroperitoneal portion of the splenic flexure, of the spleen, and of the posterior surface of the stomach repeatedly have been overlooked at celiotomy (Case 7). Seldom, if ever, are such wounds missed by a thoracic approach. Objection has been raised to dealing with wounds of the colon and small intestine through the chest, with the contention that infection of the pleural cavity may result. This

*Major Larry M. Shefts has recently seen two cases of cardiac tamponade.

objection is not valid in that whenever a wound of the diaphragm exists, contents of perforated hollow organs beneath the diaphragm will be sucked into the pleura prior to operation. Thoracotomy makes possible the thorough evacuation of feces, stomach content, or intestinal content which may be present in the pleural cavity. It is felt that in left thoraco-abdominal wounds it is wise to accomplish all surgery in the left upper quadrant of the abdomen through the thoracic approach even when it is known that a celiotomy must be done in addition.

The site of elective thoracotomy incision for thoraco-abdominal wounds is usually the ninth or tenth rib bed or interspace. Many of these thoraco-abdominal wounds involve the eighth, ninth, tenth, or eleventh ribs or interspaces. Incision in the ninth to eleventh rib bed or interspaces may be extended forward through the abdominal wall to facilitate necessary procedures within the abdomen. It is desirable to extend these incisions into the abdominal wall one or two inches if it will obviate the necessity of a separate large abdominal incision. Small muscle-splitting incisions are indicated for subdiaphragmatic drainage or exteriorization of mobilized loops of the colon.

Wounds and incisions of the diaphragm are repaired with interrupted sutures of fine cotton or silk. The diaphragmatic edges may be imbricated, or the first row of stitches inverted toward the abdomen with the second row of sutures. Diaphragmatic wounds sutured with catgut have opened up in many instances (Case 8). It is not customary to crush the phrenic nerve as a routine measure in diaphragmatic wounds. If the defect repaired was a large one, intrathoracic crushing of the nerve may be indicated.

Removal of foreign bodies from the pleura or lung, suture of the pleura over lacerations of the lung, irrigation of the pleura with physiologic salt solution, and complete reëxpansion of the lung as the chest wall wound is closed should be accomplished.

Closure of thoracotomy incisions is, likewise, done with cotton or silk. Occasionally the time factor justifies the use of catgut. The time factor usually arises because of a back-log of other seriously wounded patients rather than necessity for rapid termination of the operation because of the patient's general condition.

Penicillin therapy locally and systemically is always indicated in thoraco-abdominal wounds. Some prefer the use of sulfanilamide locally in the peritoneum.

Right Thoraco-abdominal Wounds.—Thoracotomy is indicated in nearly every wound of the right diaphragm, regardless of the size of the missile or the size of the wound in the liver. Hemorrhage or the escape of bile may be profuse from the liver wound. A thoracotomy is done, and the wound in the diaphragm enlarged to permit institution of subdiaphragmatic drainage of the liver wound. Drainage should be accomplished by large Penrose drains with the gauze protruding from the inner end so that it may be packed loosely into the liver wound. Fatal hemorrhage has arisen from wounds of

the liver which have not been packed or sutured. The drains are invariably brought out *subdiaphragmatically* through a separate subcostal or loin incision, never across the pleural space.

Right thoracotomy incisions from the ninth to eleventh interspaces may be extended into the anterior abdominal wall to permit examination of the liver and hepatic flexure and right half of the transverse colon, the duodenum and head of the pancreas. This will frequently obviate the necessity of a separate celiotomy incision. Likewise, wounds of the posterior diaphragm may be enlarged to permit nephrectomy, suture of the kidney or establishment of drainage of the perinephric area through a stab incision in the loin.

Suture of the right diaphragm, as of the left, must be meticulously done. The use of interrupted sutures of fine silk or cotton is mandatory. Biliary pleural fistulae have occurred repeatedly when catgut was used (Case 8). Suture of the diaphragm to the chest wall (and drainage of the liver through the diaphragm and chest wall) is to be avoided. As on the left side, it is best to complete the chest surgery before making a celiotomy incision.

Combined Thoracic and Abdominal Wounds.—This group includes those cases in which there are both intrathoracic and intra-abdominal wounds but no involvement of the diaphragm. With rare exceptions, chest surgery should be completed before the celiotomy is done. In 15 consecutive deaths from combined thoracic and abdominal wounds, celiotomy preceded the superficial débridement of the chest wound in seven cases. In at least five of these the chest surgery should have been done first (Case 9). In only one were there definite indications for performing celiotomy first. Three cases died without surgery and the other five had chest wounds which demanded and received attention before celiotomy was done.

POSTOPERATIVE CARE

Bronchoscopic aspiration of the tracheobronchial tree at the termination of the operation has been mentioned. The writer is in agreement with those who favor its routine use. After the patient returns to the ward, if blood or secretions reaccumulate in the air passages, they should be aspirated by tracheal catheter suction. Rarely this is not adequate and bronchoscopic aspiration must be repeated. As soon as the patient regains consciousness, he may be able to cough up the secretions and blood as they accumulate. He should be given assistance, by supporting the chest and then by encouraging him to cough. This should be done as often as indicated and also routinely at intervals of two or three hours. Deep breathing exercises should be given at the same intervals. Tracheal catheter suction is often necessary at intervals for a number of days postoperatively. Likewise, bronchoscopy is indicated any time tracheal catheter suction does not accomplish the desired results. Arm exercises should be started after the first 24 hours.

Pleural Drainage and Aspiration.—Immediate postoperative needle aspiration of air from the chest, in addition to the other measures used to secure complete expansion of the lung, is important. If intercostal catheters have

been placed, they must immediately be connected with a water-seal bottle upon the patient's return to the ward. The posterolateral catheter may be kept clamped for three or four hours to allow the local penicillin time for bacteriostatic action. If pneumothorax or hemothorax recurs the catheter should be immediately unclamped. Proper attention to the water-seal bottles is most important. Errors have resulted when untrained personnel have been entrusted with their care. The water-seal bottle must be kept at least 18 inches below the most dependent part of the pleura. Whenever the bottle is emptied the tube must be clamped off. Aspiration is performed if there is any evidence of blood or air within the pleura, regardless of whether or not an intercostal catheter has been placed. Aspiration should be done daily without air replacement until the amount of blood obtained is less than 100 cc. and then every other day until the pleura is dry.

It has been found[12] that in thoracotomies, if the pleura is thoroughly washed with physiologic salt solution, wounds of the lung sutured, and the lung completely reëxpanded, the chest may be closed without drainage. In these cases postoperative aspiration of the chest has been required far less frequently than when intercostal drainage has been employed.

Intercostal nerve block is indicated for the relief of pain in the postoperative period. It is seldom necessary when it has been done at the time of operation or when the intercostal nerves have been crushed at operation.

Medication.—Morphine should be used in small doses, if at all, in the postoperative period. Atropine sulfate may be useful in combating excessive secretion in the tracheobronchial tree. It will not remove blood and mucus, nor eliminate the necessity of tracheal aspiration.

Oxygen Therapy.—In severe wounds of the chest, it is well to continue oxygen therapy postoperatively. This is continued until all dyspnea has disappeared. The patient is then gradually weaned from oxygen.

Penicillin Therapy.—The use of penicillin is recommended in the care of all intrathoracic wounds. A dosage schedule suggested by Major Champ Lyons has been followed. Twenty-five thousand units in 25 to 50 cc. of physiologic salt solution are instilled into the pleura just prior to closure. Twenty-five thousand units are given intramuscularly every three hours for a minimum of five to seven days and until, in the judgment of the surgeon, the danger of infection is past. This usually means the lung is completely expanded, all consolidation resolved, and the pleura free of fluid and air.

Postoperative Activity.—Patients, even with thoracotomies, are encouraged to get out of bed as soon as water-seal catheters have been removed or as soon as they feel like it, providing their general condition or other wounds do not contraindicate. When feasible, it is desirable that patients having thoracotomies remain in the institution where the surgery was performed for 10 to 14 days following surgery. Occasionally wounds which require surgery in base hospitals warrant more rapid evacuation of the patient. The tactical situation has, at times, made it necessary to evacuate these patients earlier.

Complications.—Postoperative complications in chest wounds are relatively

rare. Early empyema occurs in only a small percentage of cases. These are usually managed first by closed intercostal drainage and a little later by rib resection and open drainage. It is unwise to attempt to evacuate these patients while still attempting to maintain closed drainage. Clotted hemothorax occasionally occurs postoperatively. Unless the hemothorax is of such size as to render the patient nontransportable, he is evacuated to the Base without further surgery.

Pulmonary atelectasis, or the massive collapse of the lung of World War I, rarely occurs if careful attention is paid to all the details which have been mentioned in the foregoing discussion. When it does occur, intercostal nerve block, tracheal catheter suction, or bronchoscopic aspiration are usually effective.

Subdiaphragmatic abscess has occurred early in a certain percentage of thoraco-abdominal wounds. If drainage has been properly provided at operation, it rarely occurs. Occasionally, however, a subdiaphragmatic abscess must be drained at a forward hospital.

Acute dilatation of the stomach occurs with surprising frequency in thoracic wounds, especially when a cord injury is associated. Its recognition should be prompt, in both pre- and postoperative periods, as death may result if the stomach is not promptly deflated.

Abdominal complications incidental to the abdominal part of thoraco-abdominal operations are encountered. If the chest wound has been properly and thoroughly managed, abdominal complications are little more serious than when no thoracic wound exists.

Anemia occurs in the postoperative period even when blood replacement therapy has been adequate for the preoperative and operative periods. Blood transfusions should be given early in the postoperative period and as indicated to maintain an hematocrit reading of at least 35.

ILLUSTRATIVE CASE REPORTS

Case 1.—An American soldier suffered a penetrating chest wound from a shell fragment. The wound of entrance was in the neck and was a sucking wound. He was given 500 cc. of plasma in a collecting station. He was held in a field hospital ten hours during which time he was given 750 cc. of plasma, and his blood pressure rose from 0/0 to 92/64. On admission to an evacuation hospital he was comatose, his blood pressure was 50/20, his right leg was flaccid, some air could be heard escaping from the neck, and râles were heard over the right chest. He was given 750 cc. more plasma, and 500 cc. of blood, but lived only two hours after reaching the evacuation hospital. Autopsy revealed 1,500 cc. of blood in the left chest, a comminuted fracture of the body of the seventh cervical vertebra, but no gross injury to the spinal cord.

COMMENT: This casualty was probably sent back to the evacuation hospital from the field hospital because of evidence of a spinal cord lesion. The notes would indicate that aspiration of the chest was not performed in either the field or evacuation hospital. Surgery of the chest wound should have been performed in the field hospital regardless of evidence of a spinal cord lesion.

Case 2.—An American soldier was received at a hospital a number of hours after incurring a left thoraco-abdominal wound and a compound fracture of the left humerus

from a shell fragment. Prior to admission, he had received 500 cc. of plasma and a sucking wound of the chest had been closed by suture (no débridement). On admission, the blood pressure was 110/70, and the pulse 120. Fluoroscopic examination showed increased density in the left chest and the mediastinum pushed to the right. A large foreign body lay in the region of the stomach. There was board-like rigidity of the abdomen. A wound of the left chest in the anterior axillary line had been sutured, and there was no evidence of sucking. He was given 500 cc. of plasma, and a transfusion of 500 cc. of citrated blood was started with the anesthetic.

Operation.—The abdomen was opened through a long left rectus incision. When the peritoneum was opened there was a gush of blood and air and the patient immediately had respiratory difficulty. A four-centimeter laceration in the dome of the diaphragm was closed with three mattress sutures of silk. Following this the patient's condition showed marked improvement. A laceration of the stomach near the greater curvature was closed. No other ruptured viscus was found. There was a small laceration of the spleen but no bleeding therefrom. A foreign body, 1 x 1 x 3 cm., was found loosely imbedded on the abdominal side of the posterior leaf of the diaphragm. It was removed. Sulfonilamide powder was dusted into the peritoneum. Shortly after the closure of the abdomen the patient developed a sucking wound of the chest at the site of previous suture. A catheter was inserted for closed drainage and the wound was packed tightly with vaselined gauze. In spite of this the patient became deeply cyanotic and died.

Case 3.—An American soldier was admitted to a field hospital two hours and 15 minutes after wounding. There was a sucking penetrating wound of the right chest, with wound of entrance in the first interspace just to the right of the sternum. The systolic blood pressure was approximately 60 mm. Hg., and dyspnea was pronounced. The heart and mediastinum were shifted to the left. There was hyperresonance over the right chest anteriorly and dullness in the right axilla and posteriorly. Oxygen therapy by face mask was instituted promptly and a needle with a flutter valve attachment was inserted in the right interspace anteriorly. Nine hundred cubic centimeters of blood was aspirated from the right pleural cavity and used immediately as an autotransfusion. With the aspiration of air and blood from the chest, the mediastinal shift was partially corrected and the blood pressure approximated normal. In another hour, however, the heart had shifted more to the left and dyspnea was more pronounced. Nine hundred cubic centimeters more of bright red blood was aspirated from the right pleura, and as this was started as an autotransfusion the patient was put on the operating table. The operation was started two hours and 45 minutes after admission to the hospital.

Operation.—A curved incision was made with the end parallel to the clavicle and sternum. A pectoral flap was turned back and the second costal cartilage and a portion of the second rib removed. The first intercostal artery and a large perforating branch of the internal mammary artery were found lacerated and bleeding. They were ligated and a laceration of the right upper lobe of the lung was sutured. The incision did not permit examination and repair of the wound in the posterior surface of the lung, nor posterior chest wall. Bleeding was completely controlled by the above procedures, so the chest was closed. In addition to the autotransfusion the patient was given 500 cc. of plasma during the operation and 500 cc. of whole blood immediately after operation. The intercostal catheter placed at operation bubbled air through the water-seal for 36 hours. The patient was in good condition but having some fever when last heard from at an evacuation hospital.

Case 4.—A German P. O. W. suffered a severe penetrating left thoraco-abdominal wound. He was admitted to an evacuation hospital about 20 hours after wounding, and in poor condition. Preoperatively he was given 1,500 cc. of blood, and 1,000 cc. more was given during the operation which started approximately 29 hours after wounding. There was a large defect in the left anterior chest wall involving the seventh

and eighth costal cartilages and ribs and the ninth rib. The skin defect was 5 x 6 cm. in diameter. Rib fragments were indriven, and muscle about the wound was necrotic and foul smelling.

Operation.—A thoracotomy through the wound was performed, making the incision over the ninth rib, and excising rib posterior to the defect. A defect, 3 x 10 cm. in size, was found in the diaphragm. The diaphragm was then incised posterior to the defect. The spleen had been cut almost in two in the middle. There was a large metallic fragment just lateral to it. Many metallic fragments were removed from along the wound tract. Splenectomy was done. The splenic flexure was mobilized and examined. It was contused but not lacerated. Approximately 1,000 cc. of blood was aspirated from the abdomen and chest during the operation. Clothing, blood clots, newspaper, and metallic foreign bodies were found in the pleura. The incision in the diaphragm was closed with one continuous chromic catgut suture and a second row of interrupted cotton sutures. The defect in the diaphragm was repaired with two rows of interrupted cotton sutures, the second inverting the first. Enough diaphragmatic substance had been lost to render the closure difficult in spite of the fact that the left phrenic nerve had been divided by the shell fragment. The pleura was washed with physiologic salt solution and 25,000 units of penicillin in solution were instilled. The defect in the pleura and chest wall was covered by a pedicled muscle flap (parsabdominalis of the pectoralis major) which was sutured to the chest wall at the margin of the defect. Muscle layers of the incision were closed with continuous catgut sutures, and the skin was sutured with cotton. At the start of the operation the blood pressure was 70/50, it rose to 115/80 during the operation, but was 90/60 at the close. Air was aspirated from the chest by catheter suction during closure and by needle aspiration at the end.

The immediate postoperative course was satisfactory. The tactical situation required evacuation of the patient on the sixth postoperative day, prior to which time a developing empyema was drained by intercostal catheter. When seen four weeks later in a general hospital, his condition was good, but the defect in the chest wall had opened and with it most of the chest wall incision. The upper lobe of the lung was partially adherent but the lower was completely collapsed. The diaphragmatic wound healed, and the cotton sutures were removed through the open chest wall wound. A plastic closure of the chest wall was accomplished about one month later.

Case 5.—An adult Italian woman, wounded by a shell fragment, was tagged at a battalion aid station with the diagnosis "shell fragment wound, through-and-through, entrance left breast, exit below the scapula posterior chest." The wound was dressed, one unit of plasma was administered, and the patient sent on to a collecting station. There, a novocaine block of the third to the seventh intercostal nerves was done. From the collecting station she was transferred to a clearing station and then to a field hospital, entering there three hours and 15 minutes after tagging at the battalion aid station. On admission, the blood pressure was 80/60, rising to 100/78 after transfusion of 500 cc. of blood and to 110/80 after a second transfusion of 500 cc. of blood. Two hundred cubic centimeters of blood were aspirated from the left chest. She was held at the field hospital eight to nine hours after admission, then evacuated to an evacuation hospital. There she was given three units of plasma, 500 cc. of blood and sulfadiazine and soda. Sixteen hours after admission, under local anesthesia, the wounds of entrance and exit were débrided, 270 cc. of blood were aspirated from the chest, and the fourth to tenth intercostal nerves were blocked with novocaine. Death occurred 15 hours after surgery. At postmortem, it was found that the missile had perforated the diaphragm, stomach, and spleen, as well as the left lung. Both empyema and peritonitis were well developed.

COMMENT: The possibility of a thoraco-abdominal wound apparently was not considered in either the field or evacuation hospital. Slight enlargement

of either wound of exit or entrance would have revealed a wound of the diaphragm. Endotracheal anesthesia should be used in the surgery of all perforating and penetrating wounds of the chest. A casualty exhibiting the degree of shock this patient suffered and having a wound which might have involved the diaphragm should have had surgery in the field hospital.

Case 6.—An American soldier suffered a large penetrating wound of the left chest. The wound of entrance was in the midaxillary line at the level of the seventh rib. Sucking was controlled with some difficulty. He was admitted to the field hospital unit about five hours after wounding with a pulse of 130, and blood pressure 76/30. He had been given 750 cc. of plasma prior to admission. He was given 250 cc. of plasma and 500 cc. of blood was started. The left chest was aspirated of 400 cc. of blood and 500 cc. of air. A needle was left in the second interspace anteriorly and connected with a water-seal. Three hundred cubic centimeters of the blood aspirated from the chest were given as an autotransfusion, and 250 cc. more of plasma was administered. Five hundred cubic centimeters more of blood were then given. Operation was performed 11 hours after wounding under endotracheal ether-oxygen anesthesia.

Operation.—The wound of the chest wall was excised and enlarged by removing the ends of the fractured seventh rib. Two large foreign bodies (0.2 x 2 cm.) were found lying together in the left dome of the diaphragm and left lobe of the liver. Some fabric was found deep to the metallic foreign bodies. These were removed. The liver was not bleeding. It was elected not to make a separate thoracotomy incision to repair the diaphragmatic wound as the liver was barely penetrated. Free rib fragments and some blood were removed from the pleural cavity. One intercostal catheter was placed in the ninth interspace posteriorly for closed drainage. The chest was closed. Another transfusion of 500 cc. of blood was given during and after the operation.

The catheter was removed 48 hours after surgery. The chest was aspirated of a small amount of bloody fluid on two occasions. The immediate convalescence was uneventful. One month after surgery, after the patient had been admitted to a general hospital, a small localized empyema developed. This was draind by rib resection, and further convalescence was uneventful.

Case 7.—This soldier had a left thoraco-abdominal wound in which omentum was protruding from a sucking wound in the posterior axillary line. On the night of the day of wounding a thoracotomy was performed. The diaphragm was repaired, but subdiaphragmatic exploration was not accomplished because of the poor condition of the patient. The chest wall wound was closed, and it was planned to do a celiotomy as soon as the patient's general condition improved. The celiotomy was performed the next morning, when the patient's condition was only fair. The peritoneal cavity contained a small amount of blood but no visceral injury was found. It was thought by the surgeon that the blood had entered the abdomen through the diaphragmatic wound before it was repaired. The abdomen was closed. Thirty hours after this operation 900 cc. of blood was aspirated from the left chest. The chest wound appeared clean at this time. Sixteen hours later the patient was found to be in critical condition. There was a large swelling extending from the chest wound up the left chest wall posteriorly and into the axillary area. The temperature was 108° F., and the pulse was very rapid and thready. On removing stitches from the chest wound foul-smelling gas and fluid escaped. The patient died very shortly thereafter, about 48 hours after the celiotomy. At autopsy, the latissimus dorsi muscle above and below the wound was three times normal thickness, dark red in color and filled with gas bubbles. In addition, it was found that there had been a laceration of the splenic flexure of the colon in its retroperitoneal portion and fecal matter was escaping through the chest wound.

COMMENT: All necessary abdominal surgery could have been accom-

plished through the diaphragm but the surgeon felt the patient's condition would not permit it at that time. The wound of the colon could not have been discovered at celiotomy without mobilizing the splenic flexure. Through the diaphragm it would have been quite apparent and indicated surgery could have been easily performed.

Case 8.—An American soldier was admitted to an evacuation hospital 2.5 hours after sustaining a perforating wound of the right chest. His blood pressure on admission was 85/60. A radiograph of the chest showed a "partial hemothorax." He was given 1,000 cc. of blood, and his blood pressure rose to 140/80.

Operation.—A thoracotomy was performed 9.5 hours after admission. Six hundred cubic centimeters of blood was evacuated from the pleura and a two-inch laceration of the right dome of the diaphragm was sutured with catgut. He was given 500 cc. of blood during the operation. Two days later his general condition was fair and he was given 500 cc. of blood. Four days after operation, 800 cc. of bile-stained fluid was aspirated from the right chest, and it was noted that the general condition was poor. Five days postoperatively, 300 cc. of bile-stained fluid was aspirated from the right chest, 500 cc. of blood was transfused and further surgery was undertaken. The chest wound was opened, two cigarette drains were run from the liver wound out through a subcostal incision, and the diaphragm was closed with interrupted sutures of silk. A tube was placed intercostally for water-seal drainage of the right pleura. The patient died a few hours after the operation. No postmortem examination was made.

Case 9.—An American soldier suffered multiple shell fragment wounds. He was given morphine and 500 cc. of plasma in an aid station, and reached an evacuation hospital 6.5 hours after wounding, with a diagnosis of "penetrating wound of the right chest, with hemopneumothorax; shell fragment wound abdominal wall, right lower quadrant; penetrating wound right shoulder, with compound fracture of right humerus; lacerated wound right hand; penetrating wound left arm." He was then given 500 cc. of plasma and 500 cc. of blood. Oxygen was administered by nasal catheter. Eight hundred cubic centimeters of blood and 300 cc. of air were aspirated from the right chest five hours and 45 minutes after admission. A celiotomy was performed seven hours after admission, 13.5 hours after wounding, and under intratracheal ether anesthesia.

Operation.—Two large areas of ecchymosis were found in the wall of the ileum and there was some blood in the lumen of the bowel, "possibly caused by blast." The compound fracture of the humerus, and the soft-tissue wounds were débrided. "The patient died unexpectedly and suddenly," 1.5 hours after the start of the operation. "The aspirated blood had been citrated, and used as an autotransfusion, and the pulse and blood pressure had been satisfactory throughout the operation. The autopsy revealed no new information but a considerable amount of blood remained in the right pleural cavity."

COMMENT: The chest wound should have been débrided first, bleeding controlled, the pleura thoroughly evacuated of blood and air, the lung completely expanded and the chest wall wound closed by suture before proceeding with the celiotomy and other surgery. The patient would then have had a more competent respiratory system during the surgery on the abdomen and other parts of the body.

SUMMARY AND CONCLUSIONS

1. Very few casualties with wounds of the chest who survive to be evacuated from the battle field should die if properly equipped trained surgeons are available for their care.

2. Severe wounds of the chest demand first-priority management, *i.e.*, prompt care and surgery in the most forward hospital installations.

3. A surgeon familiar with both thoracic and abdominal surgery is best qualified to treat severe wounds of the chest encountered in the most forward hospitals.

4. Anesthetists well trained in endotracheal anesthesia for thoracic surgery are essential to the proper care of war wounds of the chest. Endotracheal oxygen ether, administered through a closed apparatus capable of positive pressure, is the preferred anesthesia in all perforating and penetrating wounds of the chest.

5. Prompt, well directed resuscitative measures, plus thoracotomy, are essential to the recovery of those with thoraco-abdominal wounds, those with continuing intrathoracic hemorrhage, and those with large bronchial fistulae.

6. Proper occlusion of open chest wounds with gauze and adhesive strapping is the preferred management until the patient is in a hospital equipped and staffed to do intrathoracic surgery.

7. Early and repeated aspiration of hemothoraces, without air replacement, is essential to the proper management of chest wounds. Hemorrhage has not recurred because of this practice.

8. Early aspiration of large pneumothoraces and continuous aspiration by catheter water-seal drainage of pressure pneumothoraces must be accomplished to secure a high survival rate in such conditions.

9. Intercostal nerve block to relieve pain, promote deeper breathing, and to facilitate expulsion by cough of blood and mucus in the tracheobronchial tree, is an important adjunct to therapy.

10. Tracheal catheter suction has an important place in the pre- and postoperative management of chest wounds.

11. Bronchoscopic aspiration of blood and mucus from the trachea, main stem bronchi and lobar bronchi is a good practice at the termination of every operation upon a patient with a chest wound. It may be indicated in the preoperative, operative, and postoperative periods when less radical measures fail to clear the tracheobronchial tree.

12. Replacement therapy is most important in chest wounds. Whole blood is the preferred fluid. Autotransfusion of pleural blood should be used whenever practicable. Care must be exercised to give the blood slowly after the systolic blood pressure has reached 80 mm. Hg. and to give no more blood than is necessary to attain adequate resuscitation.

13. Most wounds of the chest need only débridement of the chest wall, preceded and followed by proper chest management, replacement therapy, and oxygen therapy.

14. There are certain indications for thoracotomy through the wound.

15. There are fewer indications for formal thoracotomy by separate incision.

16. With few exceptions, surgery of chest wounds should be done first in

the case of multiple wounds, thoraco-abdominal wounds, and combined intrathoracic and abdominal wounds.

17. Most thoraco-abdominal wounds are best handled first by the thoracic approach, performing a celiotomy only if abdominal wounds cannot be cared for by the transdiaphragmatic route.

18. Evacuation from the pleura of blood, air, and all foreign bodies, and irrigation of the pleura with physiologic salt solution is desirable in the surgery of perforating and penetrating wounds of the chest.

19. Complete expansion of the lung by inflating it out to the chest wall and evacuation of all pleural fluid and air should be attained at the end of all operations in which the pleura is opened.

20. Sulfonamide or penicillin therapy should be continued until the pleura is free of all air and fluid and until any lung consolidation has resolved.

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COMBINED INJURIES OF THE THORAX AND ABDOMEN

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BATTLE CASUALTIES with thoraco-abdominal wounds are especially interesting to the military surgeon not only because of the complicated problems which they may present but also because the results of surgery in even the most desperately injured of them are often so gratifying. There are special features in the preoperative, operative, and postoperative management of these patients which have little counterpart in civil practice and which can best be learned from experience. In the present war a larger proportion of patients with combined injuries of the thorax and abdomen survive to reach forward hospitals than ever before. Furthermore, recent advances in surgery, chemotherapy, and anesthesia, and the availability of blood and plasma at the front have combined to increase the scope and success of operative treatment.

This communication deals with the authors' experiences in the definitive treatment of these casualties in an evacuation hospital and with their care until their condition permits evacuation to general hospitals in the rear. This phase is the most critical one of their prolonged hospitalization because the eventual morbidity and mortality are determined as much by the treatment they receive at this time as by the severity of their wounds. The results we shall present are based only upon this period of observation. It is true that subsequent operations, with additional morbidity and mortality, may be necessary in some cases, but circumstances do not permit us to know the late results in our patients at this time. We are discussing, therefore, the problems met with, and the results obtained, in what is in military surgery a separate echelon in the total management of these casualties.

CLASSIFICATION

Eighty-three patients having injury to both the thorax and abdomen were admitted to an evacuation hospital in a six-month period. They represented 21.9 per cent of the total number of patients with thoracic injuries involving hemothorax or pneumothorax, and 24.3 per cent of those with penetrating wounds of the abdomen admitted during the same period.

In its limited sense the term "thoraco-abdominal wound" refers to one in which the causative agent has traversed the diaphragm to involve both the pleural and peritoneal cavities. This was true in 66 of our cases. There are, of course, other types of combined injury to the chest and abdomen in which the diaphragm is not injured, as in the case of separate wounds of the thorax and abdomen, blunt injury to structures in both body cavities, and penetrating wounds of one cavity with blunt injury to an organ in the other. Moreover, retroperitoneal structures, especially the kidney, may be injured by a missile traversing the chest and diaphragm without penetration of the peritoneal cavity.

For this reason we have chosen to discuss all these types of wounds under the heading "combined injuries of the thorax and abdomen." Cases of blast injury to both body cavities were not included since they present different problems and have been adequately discussed in the recent medical literature of war surgery.

We have classified the 83 cases into four principal types (Table I), defined as follows:

(1) *Thoraco-abdominal* wounds are those in which a missile enters the pleural cavity first, traverses the diaphragm, and lodges in or traverses the peritoneal cavity. This was the largest group, with 53 cases.

(2) *Abdominothoracic* wounds are those with primary involvement of the abdomen followed by perforation of the diaphragm and injury to the thoracic cavity. The 13 cases in this group were placed in a separate category because of the somewhat different problems and prognosis they presented.

(3) *Thoracoretroperitoneal* wounds are those involving the diaphragm and retroperitoneal structures (commonly the kidney) without apparent involvement of the peritoneal cavity. The six cases under this heading are grouped together since the order in which these structures were injured seemed to make little difference in the outcome.

(4) *Thoracic and abdominal* injuries include (a) separate missile wounds of both cavities, seven cases; (b) subcutaneous injury to chest and abdomen by blunt trauma, two cases; and (c) missile wounds of one body cavity associated with blunt injury to organs of the other. Two cases with penetrating chest wounds associated with contusion of the kidney in one instance and of the spleen in the other belong in the last category.

CLINICAL FINDINGS ON ADMISSION

Details of the wounds are also given in Table I. Shell fragments were the causative missiles in 67 cases and bullets in 14. There were two instances of blunt injury alone and two combined with shell fragment injury. Penetrating wounds were more than six times as frequent as perforating ones. The wounds were on the right side in 48 cases and on the left in 33. In two instances the thoracic injury was on one side and the abdominal wound on the other. Right-sided wounds predominated presumably because left-sided ones were more liable to involve the heart and aorta and to be fatal on the battlefield.

Rib fractures were known to be present in 41 cases, of which 18 had fractures of more than one rib. The chest wound was sucking, *i.e.*, an open pneumothorax was present in 27 instances. We have discussed this group in another communication. Suffice to say that the dangers of open pneumothorax served to elevate substantially the mortality rate for patients with this complication.

Shock of some degree was present in over half of the patients on admission. It was slight to moderate in 23 cases and severe in 23 cases. Many patients had received plasma or blood at forward installations before admis-

sion. Two-thirds of the patients had some dyspnea on admission. Hemoptysis was a symptom in 19 of the group.

Pneumothorax was evident roentgenologically in 30 cases and was marked in three cases of whom two had tension pneumothorax requiring intubation of the chest for water-seal drainage.

Intrapulmonary bleeding as a result of lung damage was commonly seen in roentgenograms and was well marked in 12 instances. A diagnosis of atelectasis was made roentgenologically twice. No proved cases of pulmonary blast injury were found, but blast may have been a factor in morbidity in some patients.

One patient had symptoms of morphine overdosage on admission, and it probably contributed to his fatal outcome. Most casualties had received 0.5 gr. of morphine tartrate after wounding, and at times the full effect of the drug was not evident until they had begun to recover from shock.

Signs and symptoms which helped to confirm the suspicion of abdominal involvement were hematuria (12 cases), abdominal distention (10 cases), evisceration (four cases), hematemesis (two cases), melena (one case), and drainage of gastric content or bile through the chest wound (two cases).

Half of our cases had associated injuries of which 37 were classified as slight to moderately severe and seven as very severe. The latter group included three fractures of the vertebral column with transection of the spinal cord; three compound fractures of the extremities associated with gangrene; and one instance of compound fractures of both lower legs and one forearm. Obviously, such injuries complicating thoracic and abdominal wounds, severe enough in themselves, contribute to shock and blood loss and affect the prognosis unfavorably.

DIAGNOSIS

The diagnosis of combined injury of the thorax and abdomen is not difficult if it is kept in mind that any missile penetrating the chest, especially if it enters below the nipple line, may have traversed the diaphragm and entered the abdomen. Likewise, signs and symptoms of chest injury should be looked for in wounds of the upper abdomen. Occasionally they are found in wounds of the lower abdomen as well. In two of our cases the wound of entrance was in the lateral iliac region and a fracture of the ilium was present.

History-taking can be limited to a few questions about the time of wounding, the causative missile or force, and the presence of hemoptysis, dyspnea, pleuritic and abdominal pain, hematuria, hematemesis, and referred shoulder pain. Examination of the abdomen is not particularly reliable since the muscle spasm and tenderness commonly associated with these wounds are so frequently present in wounds of the lower thorax alone.

Abdominal distention, while common in left-sided thoraco-abdominal wounds, is also a frequent concomitant of wounds of the lower left thorax associated with rib fractures. Findings such as evisceration or leakage of gastric or biliary fluid through a chest wound have, of course, obvious diagnostic significance.

Physical examination of the chest gives valuable information as to the presence and severity of hemothorax, pneumothorax, rib fractures, and mediastinal deviation, and should be done carefully.

Except in the case of perforating wounds where thoracic and abdominal injuries are known to be present by the location of the wounds of entrance and exit, the crux of the diagnosis is the roentgenologic examination. The information which the surgeon desires includes the number and extent of rib fractures and bony damage to the spine and pelvis; the degree of hemothorax, pneumothorax, atelectasis, and lung hematoma; the presence or absence of air under the diaphragm; and most important, the number and location of foreign bodies, so that he may reconstruct the course of the missile from the wound of entrance. The services of an expert roentgenologist are most helpful in this regard. Most often the foreign bodies were reported to lie in the abdomen or abdominal wall (34 cases). In 20 the missiles were within the thoracic cavity or in the chest wall, and in six there were foreign bodies in both the chest and abdomen. In a few cases patients either died before roentgenograms were made or were operated upon without films because of the obvious and desperate nature of their injuries. It was sometimes difficult to determine whether a particular foreign body was above or below the diaphragm in the roentgenogram. If this were the case in a left-sided wound it was thought best to assume that the peritoneal cavity had been entered and to plan the operation accordingly.

As a usual procedure anteroposterior and lateral films of the chest and abdomen were made in suspected cases. In a few cases of penetrating wounds where roentgenograms of only the chest or abdomen had been ordered, the missile was seen imperfectly or not at all in these films, and it was necessary to return the patient for additional examination to locate it in the other body cavity.

PREOPERATIVE TREATMENT

Patients thought to have combined injuries of the chest and abdomen were treated in a shock ward where oxygen therapy was instituted for those with dyspnea and cyanosis. Transfusion of blood was begun as soon as possible in those showing signs of shock and hemorrhage. Stored Type "o" whole blood was preferred to that mixed with an equal volume of Alsever's solution since multiple transfusions were often necessary. The larger volume required using the latter preparation was a hazard when given to patients with severe chest injury because they were more prone to develop pulmonary edema than were other wounded. Patients who received large amounts of blood and plasma were, therefore, observed for signs of pulmonary congestion and edema and infusions of saline were avoided.

Twenty-nine patients received 1,000 cc. of blood or less before and during surgery; 17 were given 1,500 cc. to 2,000 cc.; and six received 2,500 cc. or more. The amount of blood given depended upon the estimated loss and upon the response of the blood pressure, pulse, and hematocrit readings to

therapy. Most patients received 500 cc. to 750 cc. of plasma as well, but plasma alone was used in only nine cases.

Examination of the chest and abdomen was carried out as completely as practicable and the wounds inspected and redressed. Sucking chest wounds were occluded temporarily by a vaselined gauze dressing and tight adhesive strapping. The patient was also surveyed for associated injuries, with special regard to spinal cord damage since paraplegia may go unnoticed at first in a severely injured patient.

Hemopneumothorax large enough to produce considerable dyspnea required preoperative aspiration in seven of our cases, and in two instances intubation of the chest with water-seal drainage was instituted for tension pneumothorax.

The routine use of a Levine tube for gastric distention before surgery is recommended, particularly in left-sided injury. The tube does not interfere with the administration of the anesthetic and may be left in for resumption of gastric suction on the postoperative ward.

Penicillin therapy was begun in all cases in dosages of 20,000 units every four hours given intramuscularly. Sulfadiazine was not given by mouth to patients with suspected abdominal injury. In some instances sodium sulfadiazine was given intravenously. The administration of morphine was kept to a minimum, 1/8 gr. intravenously or 1/6 gr. hypodermically being given for pain if necessary. The urine was always examined grossly for blood and a specimen sent to the laboratory in doubtful cases.

Patients with dyspnea were more comfortable reclining on a back rest, and when out of shock and comfortable without oxygen they were sent for roentgenograms in this semisitting position.

Chest films were taken with the patient sitting when possible, but in many cases they were taken with him reclining or supine, and occasionally even through the litter. The manipulation attending the taking of roentgenograms not infrequently was followed by an increase in pulse rate and fall in blood pressure in severely wounded cases, and they were allowed to recuperate with oxygen therapy for a time before being sent to surgery.

The interval between wounding and admission varied considerably, depending on the tactical situation. The average interval between wounding and surgery was 17.6 hours. The time interval between admission and surgery averaged 11.4 hours, but also varied considerably, depending on the patient's response to shock therapy, the seriousness of his wounds, and the number of other urgent cases on the surgery schedule.

OPERABILITY

Thirteen of the 83 patients in our series were not operated upon. Ten were considered inoperable and in three no operation was thought to be indicated. Of the latter group, two had small penetrating right-sided thoracoabdominal wounds with minimal hemothorax and roentgenologic evidence of small shell fragments in the liver. Both patients were evacuated on the

second day without operation. Cases with small perforating gunshot wounds of the right costophrenic sinus and right lobe of the liver not associated with rib fractures would also belong to this category. The other patient was a 17-year-old French girl who had sustained a penetrating shell fragment wound of the right lateral inferior chest six days prior to admission. There was profuse biliary and seropurulent wound drainage and roentgenograms showed a moderately large hemothorax with several shell fragments in the right lobe of the liver. The chest fluid soon became frankly purulent and frequent aspirations and instillation of penicillin were carried out. She made good progress until the time of her evacuation to a civil hospital. Subsequent surgical drainage of the empyema and removal of the foreign bodies from the liver were recommended.

Eight of the ten patients who died without surgery expired 12 hours or less from the time of admission. Two patients sustained severe blunt injury to the left side of the chest and abdomen followed by shock, dyspnea, and hematuria, and one of them had a bilateral pneumothorax, tension in type, on the left side. Another patient had a penetrating left thoraco-abdominal wound with tension pneumothorax as well as multiple shell fragment wounds and fractures of three extremities and evidence of an overdose of morphine. Two other left-sided cases and one right-sided case died of shock and hemorrhage which did not respond to multiple transfusions. One patient with separate perforating gunshot wounds of the right side of the chest and left side of the abdomen died five minutes after admission. The eighth patient was admitted 50 hours after he had sustained a penetrating wound of the right lumbar region associated with hemopneumothorax. He was in fairly good condition on admission but soon afterward suddenly began to cough up bloody fluid, and died within a few minutes, presumably from aspiration of chest fluid through a bronchopleural fistula. Another patient with a penetrating chest wound involving the subclavian artery and a perforating wound of the abdomen died of shock 20 hours after admission. It was decided to forego operation in the case of the tenth patient because of his poor prognosis and because operation could accomplish little. A bullet had entered the right iliac region, fractured the ilium and three lumbar vertebrae extensively, producing a cord transection, and had lodged in the lateral costophrenic sinus where a small hemothorax was evident. A large retroperitoneal hematoma and kidney injury were believed to be present. He died on the sixth day after admission.

Except in such cases in which operation offered nothing, however, every attempt was made to get severely wounded patients to the operating room if it was thought that shock therapy could do no more to improve their condition. The arrest of hemorrhage at operation may offer them the only chance of surviving. Three of the operative deaths in our series occurred on the table after such procedures, but the lives of several patients with an almost equally bad prognosis were saved.

The surgeon must be concerned with the total mortality rate rather than

the operative mortality and must not hesitate to attempt to decrease the former at the expense of the latter. Excluding the three cases for whom no operation was indicated, our operability rate was 70 in 80 cases, or 88 per cent.

OPERATION

The choice of operative procedure depends almost entirely upon which organs have been injured and to what extent. The anatomic involvement in the 70 operated cases is given in Table II. The surgical approach to these concomitant injuries of the thorax and abdomen is the most important point in technic. The decision to operate through the thorax, the abdomen, or both, should be dictated by certain indications, rather than by the surgeon's personal preference for working in either the chest or abdomen.

The operating time is an important consideration in these patients and major operative procedures on both the thorax and abdomen should be avoided if a single approach will suffice. Thus, only 12 of our 70 operated cases were subjected to both thoracotomy and celiotomy.

The five principal types of operation are listed in Table III, and the details of operations in Table IV. The indication for these will be discussed separately in the following paragraphs:

(1) *Thoracotomy with Transdiaphragmatic Operation:* The selection of this operation should have as its first requisite the presence of sufficient thoracic involvement to warrant thoracotomy, irrespective of the type and extent of abdominal involvement. The usual indications for thoracotomy are: The presence of large retained foreign bodies in the thoracic cavity; extensive compound rib fractures with indriven fragments; large sucking chest wounds; severe hemothorax thought to be due to lung laceration or to major bleeding from the parieties or mediastinum; and diaphragmatic herniation.

Thoracotomy was indicated in over half of our patients and sufficed in 30 cases, the abdominal exploration and repair being performed transdiaphragmatically. Of particular significance in this regard is the data in Table II. In the 70 operated cases the liver was involved 39 times, the stomach 15, the spleen 15, the kidney 12, the small intestine five, and the large intestine five. The three organs most frequently involved, therefore, are for the most part accessible to transdiaphragmatic approach, and, in fact, are more easily operated upon than by the transabdominal route. On the other hand, involvement of the kidney, small intestine, and colon, organs best approached by other routes, is less frequent. In one case, however, thoracotomy and removal of a shell fragment in the right lower lobe of the lung was performed through a kidney incision after suture of a lacerated kidney. In another instance transthoracic repair of a kidney was performed, and in a third case exteriorization of a perforated splenic flexure of the colon was effected by stab incision of the abdominal wall during a transdiaphragmatic operation.

Fractures of the sixth, seventh, or eighth ribs were commonly present in

TABLE I

CLASSIFICATION AND CLINICAL FINDINGS IN 83 CASES OF COMBINED INJURY OF THE THORAX AND ABDOMEN

Type of Wound	Total Cases	Penetrating Wounds		Perforating Wounds		Penetrating and Perforating Wounds		Right-Side Wounds		Left-Side Wounds		Bilateral Wounds		Total	
		Shell	Bullet	Shell	Bullet	Shell	Bullet	Lived	Died	Lived	Died	Lived	Died	Lived	Died
1. Thoraco-abdominal	53	43	4	1	3	2	0	29	5	17	2	0	0	46	7
2. Abdomino-thoracic	13	8	1	1	2	1	0	4	0	3	5	0	1	7	6
3. Thoraco-retroperi-toneal	6	3	0	2	1	0	0	5	1	0	0	0	0	5	1
4. Thoracic and abdominal:															
a. Separate missile wounds	7	4	0	1	1	0	1	1	2	0	3	0	1	1	6
b. Subcutaneous injury	2	0	0	0	0	0	0	0	0	0	2	0	0	0	2
c. Subcutaneous injury and missile wounds	2	1	1	0	0	0	0	1	0	1	0	0	0	2	0
Totals	83	59	6	5	7	3	1	40	8	21	12	0	2	61	22

TABLE II

INVOLVEMENT OF ABDOMINAL ORGANS IN 70 OPERATED CASES

Type of Wound	Total Cases	Right	Left	Total Lived	Total Died
1. Diaphragm only:					
a. With diaphragmatic hernia	2	0	2**	1	1
b. Without diaphragmatic hernia	3	2	1	3	0
2. Liver only	27	26	1	24	3
3. Spleen only	7	0	7**	7	0
4. Kidney only	5	5	0	5	0
5. Stomach only	5	0	5*	3	2
6. Liver and kidney	5	5	0	4	1
7. Spleen and kidney	2	0	2	1	1
8. Stomach and liver	3	0	3	2	1
9. Stomach and spleen	2	0	2*	1	1
10. Stomach, liver and spleen	1	0	1	1	0
11. Stomach and small intestine	2	0	2	2	0
12. Stomach, colon and spleen	1	0	1*	0	1
13. Stomach, liver, small intestine and colon	1	0	1	1	0
14. Small intestine and liver	1	1	0	0	1
15. Small intestine, colon and liver	1	1	0	1	0
16. Colon and spleen	2	0	2	2	0
Totals	70	40	30	58	12

*Each asterisk represents one instance of associated diaphragmatic hernia (total number 7).

lateral wounds, and of the ninth and tenth in posterior wounds. The incision was usually made over the fractured rib and included the wound of entrance which was excised. Resection of the fractured rib was performed in two-thirds of the cases. In the others intercostal thoracotomy was performed. Suture of the lung was necessary in eight cases. In five cases foreign bodies were removed from the lung or pleural cavity, and in seven diaphragmatic

TABLE III

TYPES OF OPERATION IN 70 OPERATED CASES

		Right		Left		Total	
Operation	Total	Lived	Died	Lived	Died	Lived	Died
1. Thoracotomy and transdiaphragmatic operation	30	13	3	10	4	23	7
2. Thoracotomy and transdiaphragmatic operation with celiotomy	12	7	1	2	2	9	3
3. Celiotomy	18	6	1	10	1	16	2
4. Kidney exploration	3	3	0	0	0	3	0
5. Miscellaneous minor operations	7	6	0	1	0	7	0
Totals	70	35	5	23	7	58	12

TABLE IV

DETAILS OF OPERATIVE PROCEDURES

Procedures	Total	Thoracotomy and Transdiaphragmatic Operation	Thoracotomy and Transdiaphragmatic Operation with Celiotomy	Celiotomy	Kidney Exploration	Miscellaneous Minor Procedures
Repair of diaphragmatic hernia	7	7	0	0	0	0
Repair of liver by suture	19	5	8	6	0	0
Repair of liver by packing	4	1	2	1	0	0
Repair of stomach	14	6	2	6	0	0
Splenectomy	12	7	2	3	0	0
Nephrectomy	2	0	2	0	0	0
Suture of kidney	6	2	0	1	3	0
Suture of small intestine	4	0	1	3	0	0
Resection and end-to-end anastomosis of small intestine	2	0	1	1	0	0
Exteriorization of the large intestine	5	1	1	3	0	0
Wound débridement, chest aspiration, *etc.*, only	7	0	0	0	0	7

herniae were reduced. Phrenic emphraxis was done only once since function of the diaphragm in reëxpansion of the lung seemed more important than other considerations. Closure of the diaphragm was made with No. 2 chromic catgut and medium silk sutures overlapping the leaves. The thoracic wall was closed preferably with two layers of muscles. The skin was closed with interrupted sutures. Dependent closed intercostal drainage was instituted with a No. 18 F. catheter.

Thoracotomy was performed on the right 16 times, the usual abdominal injury being a penetrating wound of the liver with a retained missile. If

the perforation of the diaphragm was of some size it was enlarged and the dome of the liver exposed and sutured if necessary. Drainage of the abdominal cavity to permit the escape of bile can be done by stab incision of the abdomen made through the diaphragm. While celiotomy is necessary for many large wounds of the liver which may require packing some may be managed transdiaphragmatically by the application of a vaselined gauze pack brought out through the abdominal wall under the diaphragm. The problem of hemorrhage from the majority of missile wounds of the liver is not as great as that in fracture of the liver seen in civil practice.

In the 14 left-sided injuries in this group transthoracic repair of the stomach was performed six times and transthoracic splenectomy seven times. From the technical standpoint both removal of the spleen and repair of the stomach are more easily performed through the chest. The difficulties in exposure for splenectomy and repair of high perforations of the stomach by celiotomy are well known. Likewise, suture of the diaphragm and repair of diaphragmatic hernia are more awkward and time-consuming by the transabdominal approach.

There were seven deaths among these 30 patients. Three severely wounded patients died of shock after operation, and a fourth of massive pulmonary hemorrhage. Two died with empyema; one patient had a bilateral empyema, secondary to bilateral bronchopneumonia and tension pneumothorax with bronchopleural fistula on one side. The other patient developed gangrene of the left lower lobe and empyema secondary to an abdominothoracic shell fragment wound in which feces from the splenic flexure of the colon had contaminated the pleural cavity.

(2) *Thoracotomy and Transdiaphragmatic Operation, Combined with Celiotomy:* Both operations are, of course, necessary when indications exist for each. In this event the operation calculated to do the patient the most immediate good should be undertaken first. Usually thoracotomy, with evacuation of the hemothorax, arresting of the bleeding, or closure of a sucking wound is most compelling.

When a thoracotomy has been performed first the decision to explore the abdomen as well depends primarily upon the presence of perforation of the intestine. The latter may be obvious at transdiaphragmatic exploration, or may have been suspected from the clinical findings or from the presence of intra-abdominal foreign bodies in the roentgenograms, especially if these are lodged below the level of the first lumbar vertebra. Occasionally the surgeon may have decided that the necessary exploration and repair could be carried out through the thorax only to find at operation that the injuries were less accessible or more extensive than he had calculated. For example, he may find that an injury to the liver requiring suture or packing extends to its inferior surface. In severe intestinal injury with intra-abdominal bleeding, however, celiotomy may be required first.

Four of the 12 cases in this category were subjected to thoracotomy first, then celiotomy through a separate incision. Transthoracic splenectomy in

one instance and repair of the liver in another actually sufficed but celiotomy was performed because of the possibility of perforation of the intestine. In a third patient a large anterior laceration of the liver was found at thoracotomy, and it was closed with the aid of free omental grafts through an abdominal incision. The fourth patient exemplifies how extensive thoraco-abdominal injuries may be and be operated upon successfully. At thoracotomy, perforations of the stomach and of the left lower lobe of the lung were sutured, a laceration of the liver sutured, and a diaphragmatic hernia repaired. At celiotomy, six inches of gangrenous jejunum was resected and an end-to-end anastomosis performed; an additional perforation of the jejunum was sutured, and a perforated portion of the transverse colon was exteriorized.

A fifth patient had a preliminary celiotomy for bleeding from the liver followed by thoracotomy and suture of the diaphragm.

Seven patients in the series had wounds involving tears of the attachment of the diaphragm to the chest wall, and a single incision sufficed to permit exploration of the involved portions of both cavities and reattachment of the diaphragm. In two of these nephrectomy was necessary, and the kidney incision was carried anteriorly to the flank to permit suture and packing of a liver wound in one instance, and splenectomy in the other. In two patients a right flank incision was employed for repair of wounds of the liver and diaphragm. Combined operation through an anterior approach was done in three other cases. In two of these repair and packing of the liver and closure of the anterior pleural defect were performed through a right rectus incision. The other patient had eviscerated through perforating wounds of the upper abdomen and had a sucking defect of the diaphragm anteriorly. A transverse upper abdominal incision was used in this instance.

The last mentioned patient and one of the two in whom nephrectomy was performed died on the operating table while attempts were being made to control hemorrhage. A third patient with severe liver and kidney injury died of anuria and uremia a week postoperatively. These represented the three deaths among the 12 patients subjected to combined thoracotomy and celiotomy.

(3) *Celiotomy:* Celiotomy alone is indicated in that group of patients in whom injury of the chest has been minimal and injury of the colon, small intestine, or inferior surface of the liver is suspected. Not infrequently, local débridement of chest wounds and closure of the pleura may be needed and often postoperative aspiration of an hemothorax must be done. If there is a considerable hemothorax, closed catheter drainage of the pleural cavity for 48 hours should be performed. If contamination of the pleural cavity by gastric content or bile has occurred drainage of the chest should be continued longer and intrapleural penicillin therapy instituted daily. Perforations of the diaphragm should be closed after aspiration of the pleural cavity with a sucker inserted through the diaphragm. Suture of the diaphragm from the abdominal approach is liable to be difficult, especially on the right.

Eighteen patients were subjected to celiotomy alone or in combination

with minor chest procedures including aspiration of the pleural cavity or closed drainage. The operative procedures require no discussion here and are listed on Table IV. There were two deaths in the group. One patient died of bilateral bronchopneumonia and atelectasis following a right-sided wound of the liver and duodenum; the other had separate penetrating wounds of the thorax and stomach with a compound fracture of the femur and gangrene of the lower leg. He died with an empyema the day following amputation.

(4) *Exploration of the Kidney:* Three patients in the group of thoraco-retroperitoneal injuries were operated upon by an incision permitting exposure and suture of the kidney and suture of the diaphragm. The latter was done in two cases. In each instance, thoracic injury was minimal, and considerable hematuria was the indication for the operation. There were no deaths in this group.

(5) *Miscellaneous Minor Operations:* Into this category fall that group of minimal concomitant thoracic and abdominal injuries from small missiles which in passage through the thorax cause damage insufficient to warrant more than aspiration of a hemothorax or hemopneumothorax and which, likewise, have produced damage in the abdominal cavity which needs no operative treatment. The classical cases are those involving the right side of the body in which one finds a small chest wound with a small hemothorax and roentgenologic evidence of a small shell fragment in the liver. Accurate reconstruction of the course of the missile from its entrance to its lodgement is important if futile major operations are to be avoided.

There were seven patients treated by relatively minor procedures. One had a left-sided wound with suspected involvement of the spleen and subdiaphragmatic bleeding. This conservative treatment was undertaken with some misgiving because of the danger on the left side of gastric perforation. Pain in the shoulder was present, a sign which usually indicates diaphragmatic irritation. In general, a conservative management of left-sided lesions is not recommended. Six patients had right-sided wounds, four of which involved the liver and one the kidney. In the other case, the pleural and peritoneal cavities had been opened by the missile without any visceral damage. Local débridement of the wounds with or without chest aspiration was carried out. In three cases small tears in the pleura were closed and in one a peritoneal laceration was sutured. There were no deaths in the group and all patients were evacuated in good condition.

ASSOCIATED INJURIES

In over one-half of our patients additional operations for associated injuries were required, among which compound fractures of the extremities were most common. As a rule débridement and plaster encasement was done at the end of the more urgent operation. In severely injured patients, however, operation upon an extremity was sometimes delayed from 24 to 72 hours. The possibility of the development of serious infection in an untreated

contaminated wound is not inconsiderable but is a less serious risk than subjecting a patient already in shock to further blood loss and trauma. The systemic use of penicillin and sulfadiazine, with adequate immobilization of the extremity, lessens the chance of serious infection.

When débridement of compound fractures of the humerus was done along with a thoracic operation, the temporary use of a full-arm plaster encasement is sufficient for immobilization in the hospital. A Velpeau plaster dressing was applied for transportation. In two patients leg amputations were performed and one an arm amputation.

ANESTHESIA

Endotracheal ether anesthesia was employed in 50 of the 70 operated cases, and 13 others were given an ether-oxygen mixture from the anesthesia machine. The former was preferred both for thoracotomy and for celiotomy because an air-way was assured, respiration could be controlled; upper abdominal relaxation was improved; and aspiration of tracheobronchial secretions during and after surgery was facilitated.

Sodium pentothal supplemented by nitrous oxide and oxygen was used in three cases where operation was limited to débridement and exploration of the wound. Local procaine infiltration sufficed in three other procedures of this type, and was also employed in one patient with severe shock and hemorrhage associated with evisceration through the chest wound. Generally speaking, the application of agents and methods other than the endotracheal administration of ether was limited to exploration of kidney wounds and right-sided injuries not requiring open thoracotomy.

Postoperatively the anesthetist aspirated the trachea with a catheter, and occasionally bronchoscopic aspiration was carried out. If the patient was in poor condition at the end of the operation, he was kept on the table for an hour, or more, while the administration of oxygen and blood was continued before being sent to the postoperative "chest and abdomen" ward.

POSTOPERATIVE MANAGEMENT

Oxygen therapy was usually continued on the ward for several hours after operation. Blood and plasma were given as necessary for continuing or increasing shock and signs of pulmonary edema were watched for. Apart from the treatment of postsurgical shock, over one-third of these patients required additional transfusions during the postoperative period.

Gastric suction was instituted in left-sided cases and in any patient in whom gastric distention had been present preoperatively. Right-sided wounds were less troublesome in this regard. Three thousand cubic centimeters of dextrose in water or saline and 250 cc. of plasma were given daily to patients with gastric suction.

The usual precautions for the prevention of atelectasis were observed. Patients who had not had a celiotomy were allowed to recline on a back-rest and to sit up as soon as practicable. Deep breathing exercises were started at the outset to encourage reëxpansion of the lung.

The administration of penicillin intramuscularly in doses of 20,000 units every four hours was continued. Six grams of sulfadiazine a day was given orally to patients without gastric suction, provided there was no serious kidney injury. Intravenous sodium sulfadiazine was not employed routinely, but only when such complications as postoperative atelectasis or bronchopneumonia were evident.

In patients with closed drainage of the chest, the patency of the catheter was checked at intervals by irrigation with a little saline. Forty thousand units of penicillin in 20 cc. of saline was injected into the tube before its removal 40 to 48 hours after operation. When there had been gross contamination of the pleural cavity with gastric or intestinal content or when there was much bile in the pleural fluid, however, the catheter was left in for three days or more.

Reaccumulation of the serosanguineous fluid after removal of the tube was common, especially after transdiaphragmatic operations. Usually one aspiration sufficed, since, ordinarily, no attempt was made to aspirate fluid if roentgenograms showed it to be small in amount. Other cases required two to four aspirations by reason of pleuritis due to biliary or other contamination of the pleural cavity, suspected empyema, or some other cause. Penicillin was injected after each aspiration and air was removed as completely as possible to encourage early reëxpansion of the lung.

In some instances it was necessary to transfer patients to the care of another hospital unit before they were ready to be evacuated. Our policy was to keep postceliotomy patients for ten days or longer, and postthoracotomy cases for at least seven days. Patients with nonserious right-sided or thoracoretroperitoneal injuries were often held for only three to five days. A number of our patients were evacuated by air since it was believed that they would stand the trip better by air transport at low altitudes than by ambulance or ship.

POSTOPERATIVE COMPLICATIONS

The serious complications among the patients who died following surgery have already been discussed in the section dealing with the various operative procedures and will only be summarized here.

Shock due to trauma and operation was the most common fatal complication (seven cases). Pulmonary complications were frequent and included five cases of postoperative atelectasis, four of bronchopneumonia, two of tension pneumothorax, two of pulmonary edema (both of which were fatal), three of empyema (all of whom died), two of severe hemoptysis, one of bronchopleural fistula, and one of gangrene of one lobe of the lung. Bile was evident in the pleural fluid in six instances, and there was biliary drainage from the chest wound in two patients. Many patients had some degree of hydrothorax or pneumothorax on evacuation, and it is likely that some cases of empyema and nonreëxpansion of the lung appeared after they had left our hands.

Anuria and uremia were fatal in one patient. Another developed a fecal fistula in the abdominal wound of entrance near his colostomy. Moderate peritonitis was due to contamination from perforation of the intestine in four cases, and in two others, to bile in the peritoneal cavity.

Abdominal distention persisting in spite of gastric suction was troublesome in seven patients. Some degree of wound infection was present in five cases, though it may have appeared later in other instances. Persistent paroxysmal auricular tachycardia occurred in one patient, who died. Transfusion reactions were relatively common (six cases), and were probably due to the use of stored Type "o" blood, and to the frequent use of multiple transfusions. One patient had a severe reaction with temporary renal shutdown, but recovered with alkalinization therapy.

Discussion.—Combined injuries of the thorax and abdomen in this series accounted for about one-fourth of all penetrating or perforating wounds of the chest and abdomen. Chest and abdominal wounds each give rise to problems in management; when both are present, difficulties may be doubled and certain problems peculiar to combined injuries are added. Furthermore, more than half of these patients had associated injuries of varying severity. That left-sided wounds are more serious than right-sided ones was evidenced not only by the smaller number of the former who lived to reach the hospital but also by their higher hospital mortality. Twelve of the 33 patients with left-sided injuries died, while eight of the 48 with injuries on the right side succumbed. Both patients with chest injury on one side and abdominal injury on the other died (Table I). On the right side the liver offers an important barrier to missiles and perforation of the intestine is less common than on the left.

The clinical classification of these types of wounds into four groups implies by nomenclature the possible involvement, surgical approach, and prognosis. In this series, *thoraco-abdominal* wounds were most common and exceeded the combined total of the others. *Abdominothoracic* wounds were distinctive because they were more serious than the former; six of the 13 patients in this category died, abdominal injury was more extensive, shock more severe. Three of these patients had evisceration. The term *thoraco-retroperitoneal* designates those wounds involving the thorax and the kidney. The classification is completed by including other concomitant injuries of the chest and abdomen due to separate missiles or to blunt force in a fourth group called *thoracic and abdominal* injuries. Separate wounds of the abdomen and chest were associated with the highest mortality.

From the diagnostic standpoint, it is most important first to keep in mind the frequency with which both cavities are involved in missile wounds of one or the other. While the diagnosis may be clinically obvious from the signs and symptoms and from the location of the wounds, roentgenologic search for all missiles and reconstruction of their course will reveal the diagnosis when the clinical findings are equivocal. Experience in the corre-

lation of the findings at operation with the roentgenologic data aids in predicting organ involvement and in planning the surgical approach.

Every attempt must be made to bring even the most seriously injured patients to surgery since the arrest of hemorrhage and the correction of respiratory physiology may offer the best treatment for their shock. Overcaution in delaying operation until shock therapy has produced satisfactory pulse and blood pressure readings may be fatal in these cases. Patients who require thoracotomy because of a large hemothorax or sucking chest wound usually improve during surgery. Patients with severe abdominal injury also frequently improve during operation, but to a lesser extent. Excluding three cases in whom no surgery was indicated, 70 of 80 patients were operated upon and ten died without operation, making the operability rate 88 per cent. Although operative attempts to save desperately injured casualties may prove futile, the operative mortality rate should be disregarded in the effort to save at least some of the patients.

The proper course of treatment of combined injuries varies from no surgery at all to the most extensive combined thoracic and abdominal operations. Conservative management has an important place in the treatment of right-sided injuries involving small penetrating or perforating wounds of the liver or kidney without serious intrathoracic damage. Occasionally nothing need be done; in others, débridement and exploration of the wound, closure of the opening in the pleura, and aspiration of the hemothorax is indicated. These procedures along with suture of the kidney usually suffice for thoracoretroperitoneal wounds as well. Thoracotomy was performed 42 times, but in only five instances was a separate celiotomy incision necessary, and in seven cases exploration and repair of the involved portions of the thorax and abdomen were carried out through the same incision. Transdiaphragmatic procedures on the liver, spleen, and stomach are technically easier than if performed at celiotomy. On the other hand, celiotomy alone should be performed if intrathoracic damage is minimal. If both thoracotomy and celiotomy are necessary, the one which will do the patient the most immediate good should be undertaken first. Unless intraabdominal bleeding is present, thoracotomy should take precedence, since the correction of pathologic physiology due to open pneumothorax or a large hemothorax greatly improves the patient's general condition and increases his ability to withstand other necessary surgery.

There were 22 deaths in this series of 83 cases, a fatality rate of 27 per cent.

Of the 70 patients operated upon, 12 died, a mortality rate of 17 per cent. Five of these deaths occurred among the 40 right-sided cases, and seven among the 30 patients with left-sided wounds.

The operative mortality rate among patients subjected to thoracotomy and transdiaphragmatic operation was 23 per cent (seven deaths in 30 cases). Two of the 18 patients who had a celiotomy only succumbed, a fatality rate of 11 per cent. None of the ten patients died for whom the

relatively minor procedures of wound exploration with or without suture of the kidney had been performed. Among the operated cases perforation of a hollow viscus was associated with a mortality rate of 32 per cent. When a solid viscus alone was involved, the mortality rate was 11 per cent. Injury to the diaphragm without damage to abdominal viscera was present in five cases. Diaphragmatic hernia was present in three of these and there was one death in the group.

SUMMARY AND CONCLUSIONS

Eighty-three cases of combined injuries of the thorax and abdomen treated in an evacuation hospital have been discussed. A classification of these injuries into four principal types have been presented.

The wounds were right-sided in 48 cases (eight deaths) and left-sided in 33 patients (12 deaths). Both patients died in whom the chest on one side and the abdomen on the other were involved. The operability rate was 88 per cent. Half of the patients had associated injuries.

Five principal types of operation were carried out: (1) Thoracotomy and transdiaphragmatic operation; (2) thoracotomy and transdiaphragmatic operation combined with celiotomy; (3) celiotomy alone; (4) repair of the kidney, and (5) wound exploration with suture of the pleura if necessary. The indications for each type are discussed.

Five of the 40 right-sided cases, and seven of the 30 left-sided cases operated upon died during the period of observation. The operative mortality rate was 17 per cent.

COMPOUND, COMMINUTED SKULL FRACTURES PRODUCED BY MISSILES

REPORT BASED UPON 100 CASES

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IN THE HOPE of adding something to the picture of head wounds 100 consecutive cases of compound, comminuted fractures of the skull have been analyzed. The majority of these patients had received primary treatment at institutions located nearer the front. Some reached the Head Center within a few days, others a week or two later. Here they were kept under observation and treatment until it was felt that they were well out of danger. Practically all injuries were incurred in the Italian campaign, from Salerno, in September, 1943, to, and including, the Anzio Beachhead, in mid-winter, 1944.

TABLE I

TYPES OF MISSILES CAUSING WOUNDS

Shell fragments	66
Machine gun or rifle	10
Land mine	8
Aerial bomb	6
Mortar shell	3
Grenade	1
Flak	1
Revolver	1
Miscellaneous, or unknown	4
Total	100

Wounding Agent.—As may be seen in Table I, the missiles most frequently responsible were shell fragments. The majority of these were small, varying from 3 to 15 mm. in their largest dimension, and often multiple. Only ten wounds were due to machine gun or rifle fire; eight were caused by land mines, and six by aerial bombs. While the majority were known to have been wearing helmets at the time of wounding, exact figures are not available.

First Aid.—Almost all had had sulfonilamide powder and a dry dressing applied to the wound within an hour or two of the injury. It was impossible in most instances, however, to determine the elapsed time with accuracy, to learn just how much drug had been applied, or what wound toilette had been effected. Sulfonamide tablets were recorded as having been given in some instances, though this was the exception rather than the rule ahead of the Field or Evacuation Hospitals. Data relative to loss of consciousness and amnesia were insufficient for statistical study.

Convulsions.—In view of the fact that most of these wounds involved the cerebrum, it was of interest that convulsions were quite uncommon in this echelon, *i.e.*, during the first few weeks after wounding. Excluding cases of meningitis, but five patients experienced convulsions. All of these were associated with some degree of motor weakness, and were jacksonian in

type. In one patient whose left occipital lobe wound had been incompletely débrided, convulsions which began in the right face, were the most prominent early manifestations of an occipital lobe abscess. A second individual had a few minor convulsions confined to the left face prior to the débridement of a wound in the right temporal lobe. A third patient suffered three minor left-sided attacks during the second week following débridement of a right temporal lobe wound. A fourth patient developed weakness and repeated seizures which began in the right hand, arm, and face following a wound low in the left frontoparietal region. After primary incomplete débridement, strength gradually returned, and the convulsions ceased. Reappearance of jacksonian convulsions of the same type, together with occasional mild headaches and photophobia, marked the development of a small subcortical abscess about a retained bone fragment.

Subdural hematoma occurred but twice in this series. In one case right parieto-occipital subdural hematoma was associated with an overlying pavement fracture. Improvement followed early evacuation. However, persistent lower quadrantic left homonymous hemianopsia led to an encephalogram seven weeks later. This disclosed a right parietal lobe porencephalic cyst of irregular contour which extended from the cortex to the lateral ventricle. The coexistence of subdural and subcortical hematomas was thus suggested. In the second patient a right frontal subdural hematoma of 30 to 40 cc. followed a penetrating flak wound of the underlying lobe. Recovery followed wound débridement and evacuation of the hematoma. In no case was extradural hemorrhage extensive.

Wound Infections.—By far the greatest problem connected with the treatment of compound, comminuted fractures of the skull at this echelon was infection. All told, 41 of the 100 head wounds failed to heal *per primam.* Among these were 22 deep infections, manifested by abscess, fungus, meningitis, or some combination thereof. In this group occurred the only five deaths of the series. The remainder of the infections, or 19, were limited to the extracranial wound. The prevention, early recognition, and treatment of head wound infections are thus matters of importance, second only to the initial control of hemorrhage and of increased intracranial pressure.

In studying the healing of such wounds, it is well to bear in mind that certain factors of great importance must of necessity remain indeterminate. These, in particular, are: the degree of initial soiling, the extent and amount of local tissue necrosis, and the surgical technic subsequently practiced. Those who have seen Evacuation and Field Hospitals in action will readily understand that operating conditions cannot always be ideal.

Time Factor.—Elapsed time between wounding and operation varied from a few hours to four days. The average lag for those wounds which healed by first intention was 19 hours, while for the group with infections it was 29. Delay of one or two days should by no means preclude wound débridement and tight closure. This is attested by the fact that this procedure was successfully carried out on a number of occasions three or four days after

injury. Obviously, however, the earlier the operation can be performed the better, the patient's condition and local facilities permitting.

Sulfonamide therapy was employed in the majority of cases. Its effect on the incidence and spread of wound infection was difficult to assess since we observed no comparable group of cases not so treated. Owing to the smallness of the series, and the fact that some records were inadequate, little more than a hint could be obtained relative to the value of local *versus* general use of the drug (see Table II). Of 67 patients definitely recorded as having received sulfonamide therapy either locally or generally, 29, or 43 per cent, developed wound infections. It is obvious that proper surgery

TABLE II

69 PATIENTS DEFINITELY RECORDED AS HAVING RECEIVED SULFONAMIDE THERAPY

	Healed Per Primam	Infected	Total
Local use only	18	13	31
General use only	9	10	19
Local plus general use	11	6	17
None	2	0	2
Total	40	29	69

is still prerequisite to sound wound healing. Penicillin was not available during this period.

Primary Débridement.—The general policy was to excise badly contused portions not only of scalp and bone, but of brain tissue as well. As far as possible, all dirt, hairs, bits of helmet and other foreign matter were removed. Metallic foreign bodies were extracted where accessible, provided their

TABLE III

EFFECTS OF INDRIVEN BONE FRAGMENTS ON WOUND HEALING

	Healed Per Primam	Superficial Infection	Deep Infection	Deaths	Total Infections	Total
All fragments removed at primary débridement	34	9	2	0	11	45
Part, or no fragments removed at primary débridement	19	10	20	5	30	49
Total	53	19	22	5	41	94

removal did not involve injury to important neural structures. Since indriven chips were nearly always present in this type of penetrating skull wound, their presence after operation (as demonstrated roentgenologically) was taken as an indication of the measure of completeness of débridement.

Results.—Of the 94 patients with indriven bone fragments, the wounds in 53 healed *per primam,* while the remaining 41 failed to do so. In most instances this was due to infection. The value of thorough débridement may be seen in Table III. When complete, the majority of wounds healed by first intention; such infections as occurred were for the most part superficial. On the other hand when the wound was débrided incompletely, or not at all, infection followed more often than not (in 30 of 49 cases). Moreover, the majority of the infections in the latter group were deep seated. Among them occurred all five deaths. Inadequate débridement was the largest single factor contributing to infection.

Tripod incisions gave trouble in the majority of cases. Thirteen of the 18 in this series failed to heal *per primam,* due to apical necrosis, to infection, or to both. If an additional eight examples seen in the Head Center be considered, it is found that 18 of the 26 broke down. While the trouble could not be ascribed to the type of incision in each instance, it has been sufficiently common as to suggest that the tripod incision be avoided when

FIG. 1.—One method of replacing a large area of scalp loss by a sliding flap. In this patient the skin defect was near the brow. The denuded area above was covered with a split thickness graft. (Case of Major C. E. Dowman)

possible. On the other hand, it is a convenient and sometimes unavoidable means of exposure. Occasionally one finds it ready made. Cushing used it, or its Isle of Man modification, with success in the last war. When employed, acutely-angled flaps should be avoided, and the narrowest angle placed on the side of the best blood supply. Great gentleness should be exercised in handling the flaps, particularly their apices. If apical sutures are necessary, they must be tiny and nonconstricting. Accurate closure without tension is essential. Hence, if there has been much loss of scalp tissue, the flaps must be made rather long and even converted into the Isle of Man form, in order to gain sufficient mobilization. Tension is thus avoided, or decreased, by taking advantage of the elasticity of longer skin flaps.

If the area of scalp loss be such as to preclude the use of a simple linear or curvilinear incision, a method which has been employed with success is that of a generous-sized flap, with the wound defect in its center. When débridement has been completed, the wound of entry is accurately closed, the flap then sutured back, with a wider distribution of the resulting tension. The latter, if significant in degree, can be entirely avoided by placing a split-thickness graft in the crescentic defect at the unsutured apex of the flap

Inner table depressions are easily overlooked; together with pavement depressions they made up 15 per cent of this group of cases. Tangential injury from a rapidly travelling missile may produce a fracture in the outer table difficult to detect, yet displace fragments of inner table considerably. Whether or not the dura is torn, serious trouble may follow wound infection. The following case is particularly interesting in that an apparently minor scalp wound lead to almost catastrophic complications:

Case 1.—A 21-year-old male was struck a glancing blow in the right frontal region by a rifle bullet at 1800 hours on November 7, 1943. He was momentarily unconscious. Sulfanilamide powder was sprinkled into the wound and a dry dressing applied in an Aid Station. At an Evacuation Hospital the next day, the wound was inspected, no fracture observed (roentgenologic examination of the skull was reported negative), and the skin sutured. From November 10, 1943, to November 12, 1943, there was fever of 102° F. to 103° F. and purulent wound drainage for a few days. He was subsequently evacuated through four different installations, the last of which was reached on November 18, 1943. There the temperature was found to be 104.2° F. (R); pulse 110; and respiration 30. Drowsiness, cervical rigidity and dehydration were pronounced. He was incontinent of urine. All deep reflexes were diminished. The white blood count was 23,000, and the red blood cell count 3.5 millions. Lumbar puncture was reported to have disclosed cloudy fluid under low pressure. Sulfadiazine therapy was instituted. On November 21, 1943, he was still drowsy, but rational. Two left-sided jacksonian convulsions occurred that day, each beginning in the face, and involving that entire side of the body, plus the right face, as well. Lumbar puncture then yielded cloudy fluid under a pressure of 220 mm. of water, with white cell count 1,500. Further analysis of this specimen disclosed: glucose 44 mg./100 and globulin 1+; both smear and culture were negative for bacteria. During the next two days fever and cervical rigidity continued, while convulsions became increasingly frequent and severe.

On admission to the Head Center, November 22, 1943, the patient was drowsy, but rational. He complained of severe headache and his neck was rigid. Temperature 101° F.; pulse 60; and respiration 16. The small right frontal scalp wound appeared healed save for a small central crust. Neurologic examination revealed left flaccid hemiplegia, and left hemihypalgesia, with complete asteriognosis in the left hand. There was complete left homonymous hemianopsia to repeated rough testing. The right pupil was slightly smaller than the left. The retinal veins were quite full, but the nerve heads were not swollen. The left abdominal reflexes were absent. Sustained ankle clonus was found on the left side. Examination of the eardrums was essentially negative. Roentgenologic examination disclosed a small comminuted fracture beneath the right frontal wound with slight depression of the inner table. The preoperative diagnosis was meningitis, and right intracerebral abscess.

Operation.—November 22, 1943: Under local anesthesia, the scalp incision was lengthened and reopened. The wound contained a small amount of granulation tissue but no pus. There was no edema of the nearby scalp. When the periosteum was retracted careful inspection revealed a faint circular crack. In the center the bone was

definitely pale. When a perforator opening was made nearby, 10 to 15 cc. of light yellow pus escaped under pressure. After the fracture had been isolated by ronguering, the depressed inner table (Fig. 2) was found lying in an extradural bed of pus and granulation tissue. The dura was not torn. Surrounding bone was removed until white dura was everywhere exposed.

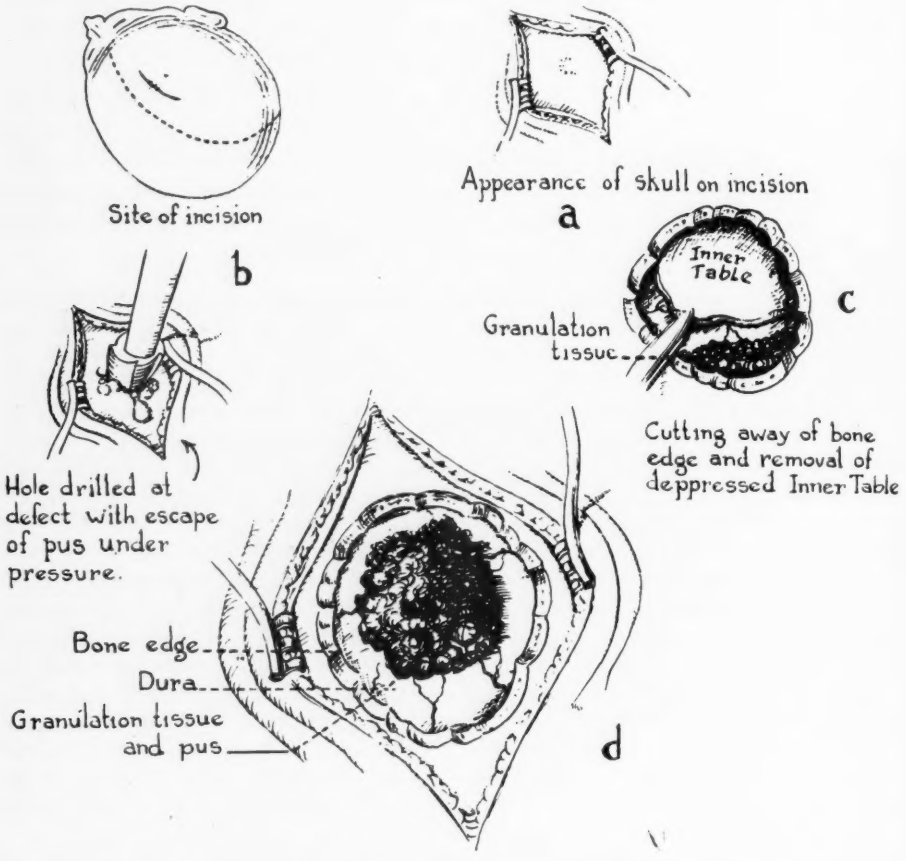


FIG. 2.—Case 1: Drawing showing steps taken to unroof and evacuate extradural abscess.

Owing to the presence of left-sided hemiplegia, hemihypalgesia and left homonymous hemionopsia it was felt that an intracerebral abscess must exist. When a tiny nick was made through an iodinized area of clean dura, several cubic centimeters of cloudy subdural fluid escaped. The small area of arachnoid visible resembled that usually seen in purulent meningitis. A ventricular needle was inserted into the frontal and temporal lobes with negative findings. The dural opening was closed with a single fine silk suture. The scalp was then sutured with silk. Sulfathiazole was given parenterally in amounts sufficient to maintain a high blood level.

Wound cultures yielded *aerobic hemolytic Streptococci.*

Convalescence was surprisingly rapid, and save for one convulsion confined to left face the day following operation, uneventful. There was a small amount of wound drainage, but this ceased within ten days. Strength and sensation returned rapidly in

the leg, arm and lastly in the fingers. The hemianopsia cleared more slowly, although within three weeks the fields had filled out about half way. A letter from him, written three months after operation, stated that he felt quite well.

COMMENT.—From the rapidity and completeness of recovery it would appear altogether unlikely that this patient had an intracerebral abscess. The left hemiplegia, hemihypalgesia and homonymous hemianopsia could be explained in the basis of right hemispheric cortical inflammation, in which the cloudy subdural fluid may have played a rôle. (Unfortunately none of it was collected for study.) Similar neurologic changes were recently observed in a soldier with chronic right-sided mastoiditis and lateral sinus thrombosis. When first admitted with meningitis until he became comatose two or three days later, left hemiplegia, hypalgesia and homonymous hemianopsia were present. Autopsy revealed, in addition to meningitis, a mat of thick subdural pus over the posterior two-thirds of the right hemisphere. It was particularly heavy over the lateral and medial surfaces of the right occipital lobe.

Dural Closure.—There is no general agreement regarding the value of dural suture at the time of primary débridement. Some neurosurgeons feel that by leaving the dura open, pus and necrotic tissue may escape, and hence the incidence and severity of deep infection be lessened. Closure was not effected in the majority of the cases of this series. It is difficult to know whether or not any of the extracranial infections actually originated intracranially, and serious complications were thus prevented by the dura having been left open. On the other hand, no instance of spontaneous evacuation of pus or necrotic tissue from beneath the dura was observed. The only possible exceptions were the five cerebral fungi unassociated with abscess or meningitis. It could equally well be argued that these herniae might not have occurred had the dura been closed; in any case their formation was of doubtful benefit! On the other hand, there were at least three cases in which dural closure by fascial graft successfully confined infection to the extracranial wound. Brief abstracts of these cases follow:

Case 2.—A male received a compound, comminuted fracture in the left anterior temperoparietal region when a shell burst overhead at 1,600 hours, on November 22, 1943. He was wearing a helmet at the time. Consciousness was not lost. Although unable to speak or to move the right hand and arm, he managed to walk to an Aid Station more than a mile away. Twelve hours later the wound was débrided, and bits of helmet, shell fragment, bone, pulped brain tissue and blood clot were removed. The dural rent was closed with a graft of temporal fascia. Sulfonilamide powder was sprinkled into the wound, and the skin closed without drainage.

Speech as well as strength in the right hand soon began to return. Two jacksonian seizures occurred on December 1 and 2, 1943. The incision was said to have healed, although when admitted to the Head Center on December 26, 1943, the wound was open and draining profusely. *Aerobic hemolytic Streptococci* were cultured from the pus. The scalp over the bony defect was pulsating normally and there were no symptoms suggestive of increased intracranial pressure. Despite the presence of rather active infection separated from the brain only by a fascial graft, neurologic signs rapidly decreased. Two weeks later when the wound had healed, speech was entirely normal, as was strength in the right hand and arm. Agraphia, which had been present soon

after injury, had completely disappeared, and only slight asteriognosis remained in the right hand.

Case 3.—A young male was struck in the right forehead by a machine gun bullet at 1,230 hours on October 27, 1943. He was rendered unconscious immediately. Sulfonilamide powder and a dry dressing were applied at an Aid Station. When examined at an Evacuation Hospital, eight hours later, he was awake and coöperative. The

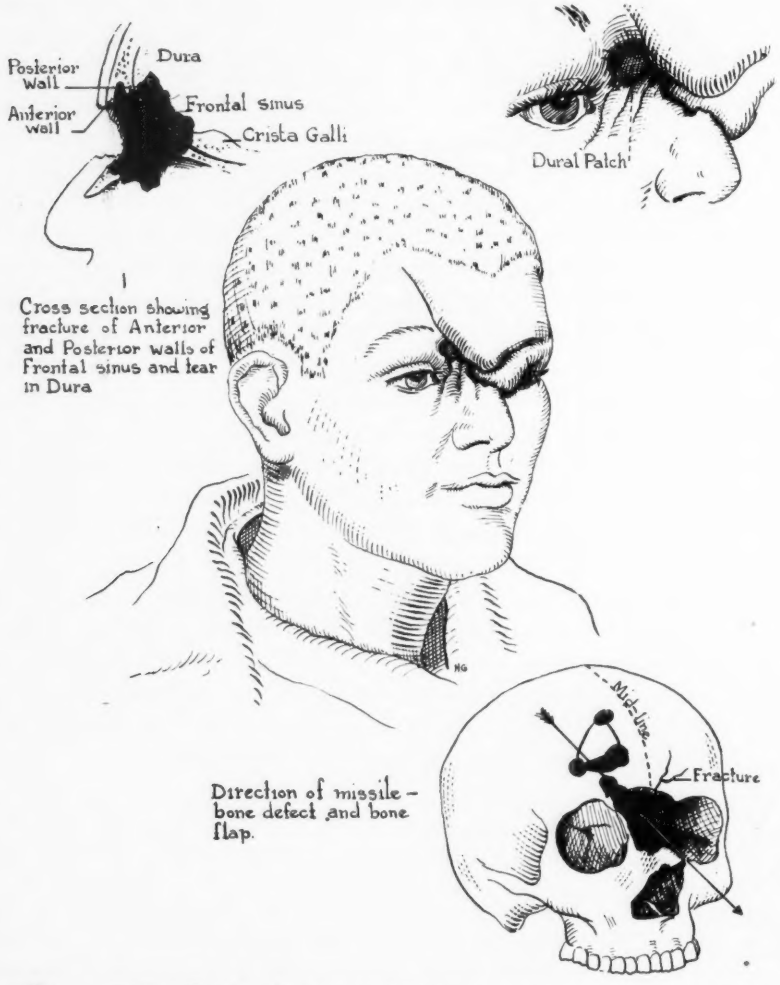


FIG. 3.—Case 3: Drawing depicting partially healed gutter wound of right frontal lobe, frontal, and ethmoidal sinuses and nose. The dural patch was still visible when this sketch was made, two months after injury.

wound was of the gutter type and extended from the right forehead to the left cheek. The frontal and anterior ethmoidal sinuses were laid open widely. The tips of both frontal poles were injured, while all tissue in the region of the nasion and glabella had been shot away. Pulped brain tissue, blood clots and cerebrospinal fluid filled the wound. Vision in the right eye was limited to light perception. No other neurologic changes were found.

Operation.—October 18, 1943 (18 hours after injury): The wound was carefully

débrided. The huge dural defect was repaired with a graft of fascia lata. As a result of extensive skin loss only the upper portion of the wound could be closed. The fascial graft was thus of necessity left widely exposed through the open frontal and ethmoidal sinuses. Sulfonilamide powder was sprinkled into the wound and sulfadiazine was administered orally.

Convalescence was remarkably uneventful. When admitted to the Head Center, November 9, 1943, an area of fascial graft, approximately 2 cm. in diameter, was exposed (Fig. 3). Granulation tissue was observed to be growing in from all sides. Within the next eight weeks not only the graft but the entire defect had been covered externally with epithelium.

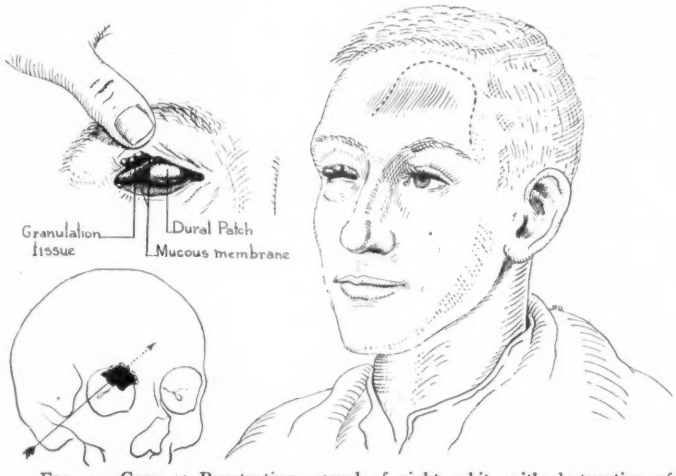


FIG. 4.—Case 4: Penetrating wound of right orbit, with destruction of eye, orbital roof, dura, frontal and ethmoidal sinuses and pole of left frontal lobe. Large dural defect repaired with fascia lata, as shown in inset 5 weeks later. (Case of Major C. E. Dowman)

COMMENT.—In this case a fascial graft afforded the sole protection to an otherwise exposed brain. That this is not an isolated result was demonstrated by a second patient (Case 4) in which both contents and roof of the right orbit had been shot away. Both frontal and anterior ethmoidal sinuses were traversed by the missile, which was removed from the left frontal lobe, 28 hours later. After débridement the large dural defect in the roof of the right orbit was closed with fascia lata. Convalescence was uneventful. When admitted to the Head Center 17 days later not only had the scalp incision healed but the graft visible through the roof of the orbit was partially covered with clean granulation tissue (Fig. 4). When evacuated two months later healing was practically complete.

While dural suture is not essential in the treatment of the majority of penetrating brain wounds, it may at times prove of definite value. Although a fascial graft may not survive an adjacent infection and have to be removed, no case was observed here in which its presence appeared to have been harmful. Dural closure is, therefore, recommended.

Deep Infections.—Abscess, cerebral fungus, meningitis, or some combination thereof, occurred in 22 of the 41 infected wounds. Abscess was present

TABLE IV

BACTERIAL FLORA OF WAR WOUNDS *(September 12, 1943 to March 1, 1944)

CASE INCIDENCE

Species	Head	Extremity Lower	Extremity Upper	Face and Neck	Miscellaneous†	Cutaneous Ulcers
Aerobic nonhemolytic Staphylococcus albus	16	60	16	7	61	46
Aerobic hemolytic Staphylococcus albus	7	15	7	1	10	18
Anaerobic nonhemolytic Staphylococcus albus	0	8	0	0	2	1
Anaerobic hemolytic Staphylococcus albus	0	0	0	0	0	0
Aerobic nonhemolytic Staphylococcus aureus	0	0	0	0	5	3
Aerobic hemolytic Staphylococcus aureus	0	0	0	1	0	0
Aerobic nonhemolytic Streptococci	5	20	2	1	6	4
Aerobic hemolytic Streptococci	5	35	11	7	25	40
Anaerobic nonhemolytic Streptococci	1	4	0	0	2	0‡
Anaerobic hemolytic Streptococci	0	6	0	0	2	0§
Streptococcus viridans	0	0	1	0	1	1
E. coli	1	6	1	0	2	2
A. aerogenes	0	13	0	0	14	2
E. coli and *A. aerogenes*	1	25	1	0	0	0
Clostridia	1	25	1	0	1	0
Proteus vulgaris	1	8	3	0	8	0
Pseudomonas pyocyanea	0	7	0	0	5	1
Cornybacterium diptheriae	0	0	0	0	0	20
Diphtheroids	1	14	3	1	1	15
Total number of cases with positive culture	23	105	28	22	62	111
Total number of cases with negative culture	2	5	3	0	0	0

*420 cultures from 250 cases of war wounds; 140 cultures from 111 cases of cutaneous ulcers.
†Cases include wounds of the chest, abdomen, back and those in which the site of the wound was not indicated.
‡Includes two strains which formed gas and occurred in wounds harboring *Clostridia perfringens*.
§One strain only was micro-aerophilic; remainder were strict anaerobes.

17 times, cerebral fungus ten, and meningitis nine. It is worthy of note that in seven cases the scalp wound had healed *per primam*. Deep infections often smouldered for days or even weeks before producing symptoms. This was quite possibly due to the fact that the infecting organisms (see below) were often of low virulence.

Bacteriology.—Approximately 50 cultures were made on 25 cases. Bacteria were isolated from the wounds of 23. Sterile cotton swabs impregnated with material from the wound were placed in tubes of brain-heart infusion broth (Difco), alone and containing sodium thioglycollate for both aerobic and anaerobic cultures. Human blood-agar media was also inoculated. The bacterial flora isolated were identified by further accepted standard methods. Table IV summarizes the species of bacteria found resident in the wounds of the 23 cases. These micro-organisms may be compared with those contemporarily found in wounds in other portions of the body.

The bacterial flora of these wounds of the skull showed a significant incidence of contamination with inhabitants of the skin—the staphylococci.

There was a small number of common bacterial residents of the oral and respiratory passages, such as pneumococci, streptococci and diphtheroids. Rarely were micro-organisms associated with soil or fecal contamination, *i.e.*, the *Coli-aerogenes* group and the *Clostridia,* observed. This is in contrast to the bacterial flora observed in 110 cases of wounds of the lower extremity in which members of the *Coli-aerogenes* group and *Clostridia* were most frequently isolated (see Table IV). Anaerobic bacteria were practically nonexistent in this group of skull wounds, whereas, quite the reverse was found to be true in the leg and thigh.

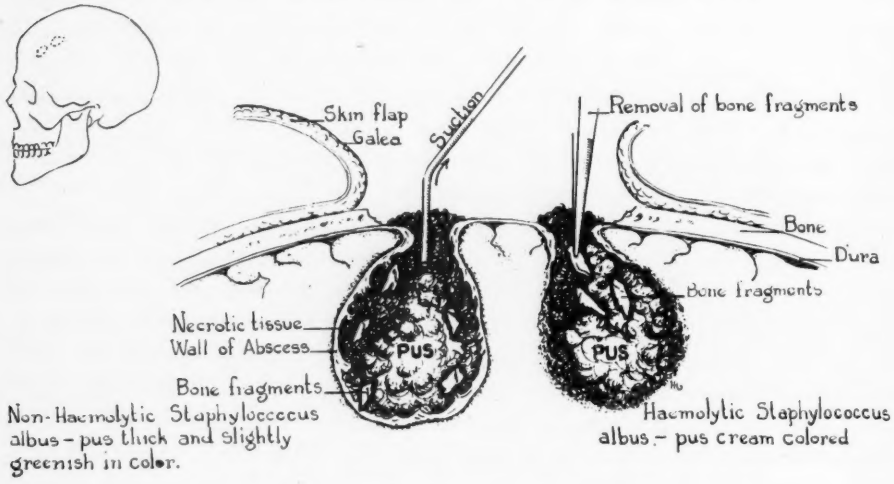
Staphylococcus aureus and *Streptococcus viridans* occurred surprisingly infrequently in this series. Strains of staphylococci were classified by their color on blood-agar after 48 hours incubation aerobically at 36°C. ± 1°. The significance of the appellation *"albus"* and *"aureus"* should be judged accordingly. The absence of streptococci producing a greening of human blood-agar media is in accordance with the infrequent occurrence of bacteria which inhabit the oral and nasal passages.

Abscess.—As a rule, the earliest symptom of abscess formation was headache. While the pain was by no means always severe, it was recurrent, usually at shorter and shorter intervals. Usually, also, it was unilateral and frequently awoke the patient from his sleep. Decreased or absent pulsation in the scalp flap became apparent later. Lumbar punctures were employed diagnostically when meningitis was suspected. All abscesses were associated with retained bone fragments and/or metallic foreign bodies. Roentgenologic demonstration of their presence after the primary débridement, therefore, should put one on guard. As has been pointed out by Ascroft, infection is particularly likely to occur where a dense cluster of chips is present within the brain. On two occasions (Cases 6 and 8) a metallic foreign body has been observed to rotate or change position; in each instance it lay free within an abscess cavity. The appearance of, or slight increase in, preëxisting neurologic signs during convalescence should make one very suspicious of deep infection. Neither fever nor leukocytosis was a prominent manifestation of early abscess.

In contrast to the predominance of common skin inhabitors among mild infections, bacteria responsible for the majority of abscesses were of greater virulence. Of seven strains of *hemolytic Staphylococcus albus* recovered from all wounds, five were associated with abscesses; the same was true for five of the six *hemolytic Streptococci,* and four of five *nonhemolytic Streptococci.* This group included most of the more serious infections. On the other hand, but five of 16 strains of *nonhemolytic Staphylococcus albus* were recovered from abscesses. Micro-organisms usually considered as soil or fecal contaminants, such as the *Coli-aerogenes* group and the *Clostridia,* and those customarily found in oral and nasal secretions, pneumococci, *streptococcus viridans,* and diptheroids, were significantly infrequent.

Abscesses in this series were not strictly comparable to those customarily seen in connection with paranasal sinus or mastoid infection. All were

associated with intracerebral foreign bodies, such as chips of bone or pieces of metal. Bone fragments sometimes lay freely within the cavity, but more often were partially embedded within the abscess wall. Necrotic brain tissue and extravasated blood in the neighborhood of the abscess, not only served to increase the intracranial pressure, but afforded ideal media for extension of the infection. Abscess walls were thickest near dura; at some distance they might be thinner, incomplete, or unformed when observed within a few weeks of the injury. As seen at this time, the majority of the cavities were not large, probably averaging not more than 10 or 15 cc. capacity.



TWIN SUBCORTICAL ABSCESSES

FIG. 5.—Case 5: Closely adjacent abscesses following penetrating wounds of left parietal lobe. One cavity had a tough capsule, while in the other there was little or no evidence of encapsulation. *Nonhemolytic Staphylococcus albus* was cultured from the first and *hemolytic Staphylococcus albus* from the second.

That the type of organism plays an important rôle in the process of the encapsulation is suggested by the following case in which abscesses developed in closely adjacent wounds. One was encapsulated, the other not; the former was infected with *aerobic nonhemolytic Staphylococcus albus* while the latter contained *aerobic hemolytic Staphylococcus albus.*

Case 5.—A young male, with a gunshot wound of the leg, was wounded in the head, November 8, 1943, when his ambulance was strafed by an enemy plane. The two left frontal wounds were débrided through a single linear incision, in a British Casualty Clearing Station ten hours later. Badly contused skin edges, bone chips and pulped brain tissue were said to have been removed. Sulfonilamide powder was dusted into the wounds, and the skin then closed with silkworm gut. Three grams of sulfadiazine was administered intravenously daily for several days. A few days later, in another hospital, he was observed to have right facial weakness and partial aphasia.

When admitted to the Head Center, November 24, 1943, he had no complaints. Slight right facial hypotonia was noted but speech was apparently normal. There was no other abnormal neurologic finding. Both frontal wounds had been débrided through a single incision, which was then healed and not bulging. Roentgenologic examination disclosed multiple small bone fragments beneath each of the two frontal bone defects.

Two days later a small amount of purulent drainage was noted from the incision. Secondary wound débridement was carried out under local anesthesia, December 7, 1943, 29 days after injury. A sinus tract leading to the anterior wound was excised, and the soft tissues widely retracted. The bone defects were closely adjacent, each was bulging with granulation tissue. Beneath the posterior opening an abscess cavity (Fig. 5), approximately 5 x 3 x 2 cm., was encountered. The supernatant pus was thick and creamy while the remainder was thinner and of a brownish color. Several bone chips lay within the cavity—unattached. Cultures from this abscess revealed *aerobic hemolytic Staphylococcus albus.*

When the anterior defect was entered, a well-encapsulated abscess, approximately 5 x 4 x 3 cm., was encountered. The pus was thick and of a greenish-yellow hue. A few bone chips were free, but the majority were adherent to, or embedded within, the thick wall of the cavity. No communication could be found between the two abscesses. Cultures from this abscess revealed *aerobic nonhemolytic Staphylococcus albus.* A small Penrose drain was left in each cavity, and the scalp closed with interrupted sutures of fine silk.

Convalescence was uneventful. There was practically no discharge, the drains were removed after 48 hours, and the wound healed *per primam.* When evacuated a month later, the scalp overlying the defects was sunken in, and pulsating well. No neurologic disturbances were present, save for mild right facial hypotonia.

Tardy encapsulation is not characteristic of all strains of the *hemolytic Staphylococcus albus,* however, as demonstrated by the following case:

Case 6.—A 29-year-old male was struck by shell fragments in the left anterior parietal region at 0600 hours on January 21, 1944. When admitted to a British Casualty Clearing Station he was semistuporous, aphasic, and unable to move the right arm. Roentgenologic examination disclosed several bone fragments beneath a compound, comminuted fracture of the left parietal bone. A large metallic foreign body was visible just beyond the midline. Eighteen hours after injury the wound was débrided, several bone chips, some clots and pulped brain tissue were removed. The large metallic foreign body was left behind. Sulfanilamide powder and flavine were said to have been implanted in the wound.

Following operation he improved rapidly. Both speech and strength in the right hand and arm began to return, headaches disappeared and the incision healed nicely. When admitted to the Head Center, February 7, 1944, he appeared to be convalescing satisfactorily. The scalp over the defect was soft and pulsating well, the incision appeared clean and he complained of no headaches. Speech was slow and painstaking, but error free. Positive neurologic findings were right hemiparesis, with hyperactive deep and diminished abdominal reflexes on that side. Position sense and interpretation of figure writing were impaired in the right hand. Slight papilledema was noted bilaterally.

Four days later the wound appeared somewhat swollen and tender, and it was thought that the right hand had become weaker. On February 13, 1944, it was quite evident that the right hemiparesis was increasing. Motor aphasia became rather marked. He had several headaches, one or two of which had awakened him from sleep. Pulsations in the flap were decreased. Roentgenologic reëxamination disclosed two small bone fragments beneath the defect. Of considerable interest was the fact that the metallic foreign body had shifted position since the taking of the first films. While it was realized that it might have been moved by the first operator, it was thought more likely that it lay within a fluid-filled cavity. It was not in the position of the ventricle, and, indeed, would have been too large to move freely therein. This served to corroborate the diagnosis of abscess.

FIG. 6A

FIG. 6B

FIGS. 6A and B.—Case 6: Lateral and postero-anterior roentgenograms of skull showing compound, comminuted fracture of left parietal area with indriven bone fragments. Note the large metallic foreign body lying just beyond the midline.

On February 14, 1944, 24 days after injury, the wound was reopened under local anesthesia. Immediately beneath the defect 10–15 cc. of necrotic brain tissue was found and removed. The larger of the two bone chips was partially embedded in the wall of a well-encapsulated abscess (Fig. 6). Approximately 66 cc. of light-yellow pus was evacuated. The second bone fragment and the metallic foreign body lay free within the cavity, the latter at the medial pole. Both were removed. The scalp was closed loosely around a small Penrose drain. *Aerobic hemolytic Staphylococcus albus* was the sole organism cultured from the pus. The drain was removed in 48 hours. There was no drainage before or afterwards.

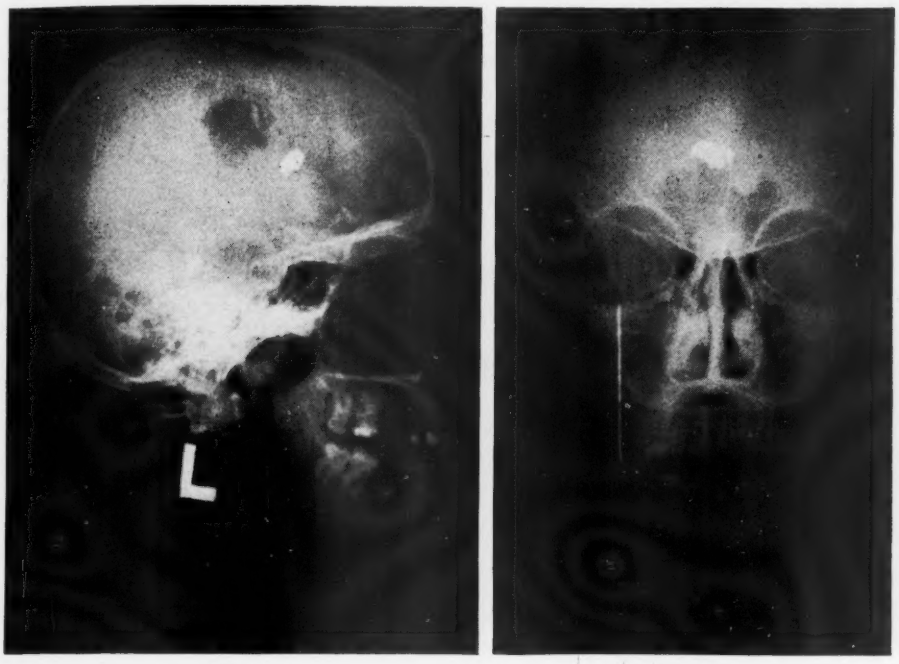


FIG. 7A FIG. 7B

FIGS. 7A and B.—Case 6: Lateral and anteroposterior roentgenograms taken before secondary débridement, showing change of position of the metallic foreign body. Two small bone fragments are visible.

Convalescence was slow but satisfactory. Within six weeks the speech disturbance had largely cleared, he walked without a limp, and strength and sensation in the right upper extremity were greatly improved. The flap was soft, sunken, and pulsated normally.

Cerebral Fungus.—This occurred in ten cases. Three were associated with abscess and meningitis, and were fatal. One arose in association with a wound infection and abscess while another occurred in the presence of wound infection and meningitis; both of these patients recovered. Five cerebral herniae were not associated with abscess or meningitis, and all healed. It was of interest that in but two of this last group of cases was the fungus of the rapidly progressive type, requiring débridement. One of these followed an untreated perforating revolver wound, extending from the left eye to the left occiput. The other, a German prisoner, suffered a perforating wound

extending from the right frontotemporal to the right occipital region. On admission to the Head Center, 15 days later, a large rather firm fungus protruded from the wound of exit. When excised, its core was found to be yellowish-red in color and rather tough in consistency. A mixed infection of *aerobic nonhemolytic Staphylococcus albus, Coli-aerogenes* and *Clostridium septicum* was found in the wound. He recovered without further complication.

Organisms cultured from fungi were for the most part skin inhabitors of low virulence. *Aerobic nonhemolytic Staphylococcus albus* were present in five, *aerobic hemolytic Staphylococcus albus* in two, *aerobic hemolytic Streptococcus* in one, and in another, the mixed infection mentioned in the

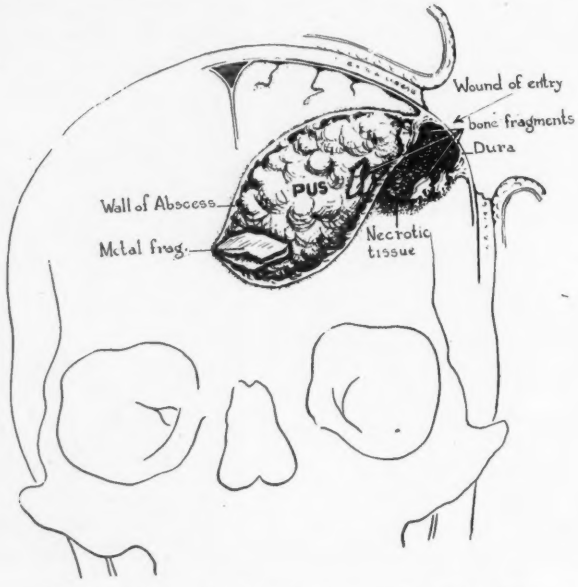


FIG. 8.—Case 6: Drawing showing metallic foreign body and two bone fragments lying free within cerebral abscess. One piece of bone is partially embedded in thick wall of abscess. Note adjacent area of necrotic tissue.

preceding paragraph. Bacteriologic studies were lacking in the remaining three. Had more virulent organisms been present it is likely that the infections would have been more difficult to cope with.

Meningitis.—This occurred as a complication of wound infection in nine patients. There were five* fatalities, all of which were associated with abscesses which were undiscovered or evacuated too late. Of the four survivors, one developed meningitis due to an *aerobic hemolytic Streptococcus* following an extradural abscess (Case 1). The other three occurred with wound infections, in but one of which there was a fungus.

Organisms identified in the wounds of patients who developed meningitis were: *Aerobic nonhemolytic Streptococcus* in three; *aerobic hemolytic Strep-*

* Including the three referred to under cerebral fungus.

tococcus in two; *anaerobic hemolytic Streptococcus* in one; and *aerobic nonhemolytic Staphylococcus albus* in three. Two had mixed infections. In three cases laboratory facilities were temporarily unavailable.

Treatment of Wound Infection.—Superficial infections required little active treatment. Bone, metallic fragments and exposed silk (particularly if heavy) were carefully removed. Hot wet dressings were customarily employed. Sulfonamides were used generally, but not locally. In several instances infections occurred in comminuted fractures of the pavement-depression type. In these cases formal débridements, with removal of bone fragments, were carried out. Wound healing then followed in each instance.

Deep Wound Infection.—This was an infinitely more serious matter, both as regards mortality and further destruction of neural tissue. While thorough encapsulation of the infection would have been highly desirable, one's hand was usually forced by the rise of intracranial pressure, by the imminence or actual presence of meningitis or fungus, and of further destruction of adjacent cerebral tissue. Bone fragments and/or metallic foreign bodies were involved in the formation of every abscess. An effort was, therefore, made to remove them as well as to evacuate pus and necrotic tissue from within the cavity. Adjacent extracapsular clots and necrotic tissue were removed with the sucker or with cotton patties. The capsule of the abscess was, of course, left behind. Stalactitic bands of fibrous tissue extending inwardly from dural edges were disturbed as little as possible. Even with good stereoscopic roentgenograms available, thorough secondary wound débridement is not always an easy matter. Abscesses may be difficult to find because of their consistency, their size, or their unexpected locations. Air studies are sometimes necessary. This general plan of treatment was carried out during the Tunisian Campaign by some surgeons, with success.

Drainage of brain abscesses was employed only occasionally. When attempted, little or no pus escaped. If the secondary débridement had been adequate, drainage was unnecessary, while if inadequate, a drain did not suffice to clear up the infection. The following cases are illustrative:

Case 7.—A 30-year-old male was wounded in the left parieto-occipital region by shell fragments at 0230 hours, December 9, 1943. Consciousness was evidently lost soon afterwards, although he subsequently remembered being hit. On admission to an Evacuation Hospital five hours later, he was lethargic and partially aphasic but able to respond to simple commands. Spastic paresis was noted in the right arm and leg, and there was some right facial weakness. The deep reflexes were hyperactive on the right and a positive right-sided Babinski sign was present. The scalp wound was triangular-shaped, measuring 3 x 1.5 cm. Roentgenologic examination disclosed an underlying bone defect of similar size, with many small indriven bone fragments. Two metallic foreign bodies were seen just below the bone defect, a third deep in the left parietal lobe, while a fourth, and larger one, lay near the falx beneath the coronal suture. Primary wound débridement was performed under local anesthesia ten hours after injury. The wound was "débrided with suction and irrigation," some pulped brain tissue, a few bone chips and the two superficial metallic foreign bodies were removed. Dura, galea and skin were closed in layers with interrupted sutures of fine silk.

Improvement was rather slow. He suffered several jacksonian convulsions the

next three days. Some drowsiness, incontinence, and fever to 101° F. were present during this period. Speech was monosyllabic. Stitches were removed on the fifth postoperative day. Both then, and as late as December 22, 1943 (13 days after operation), the wound was noted to have been cleanly healed and not bulging.

When admitted to the Head Center, December 28, 1943, he complained of headache. The temperature, pulse and respirations were normal. The two-inch parieto-occipital incision was open and obviously infected. Nominal aphasia was noted. Answers were in monosyllables. No alexia nor apraxia was present; agraphia was not tested because of flaccid paralysis of the right arm. Astereognosis was observed in the right hand. Deep reflexes were hyperactive on the right side and positive Hoffman and Babinski reflexes present in the right. The left abdominal reflexes were relatively hypoactive. There was bilateral papilledema with fresh hemorrhages and exudates.

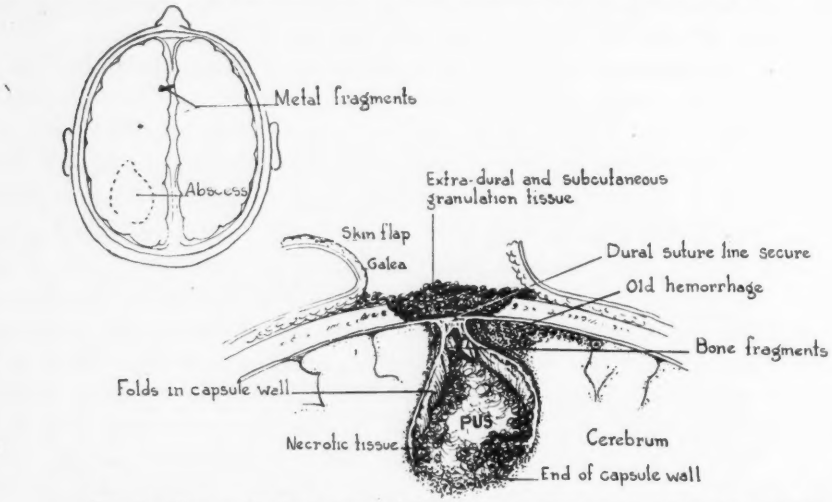


FIG. 9.—Case 7: Cerebral abscess following penetrating wound, left parieto-occipital lobe. Encapsulation incomplete. Dural suture line secure, three weeks after injury. Prompt healing followed secondary débridement.

Laboratory Data.—Roentgenologic examination revealed many small bone fragments beneath the defect. The two nearest metallic foreign bodies had been removed. The white blood cell count was 5,900, and the hemoglobin 12 Gm. (Sahli). The urine was normal. Wound smear disclosed numerous gram-positive cocci, subsequently identified as *aerobic nonhemolytic Staphylococcus albus.*

Operation.—December 29, 1943: Under local anesthesia, the wound was widely reopened, pus and granulation tissue being found down to the dura (Fig. 9). The latter had remained snugly closed but was tense, and not pulsating. The bone edges were ronguered away, and the dura then opened. A small collection of pus was encountered, and evacuated. This was walled-off on its dural side, the capsule having faded out at a depth of 2.5 cm. Necrotic tissue, old blood clot and several bone chips were then removed, leaving behind viable-appearing tissue. No attempt was made to extract the two distant metallic foreign bodies. Brain pulsations were fair at the end of the procedure. The scalp was closed in layers with interrupted sutures of fine silk without drainage. No sulfonamide was used locally, but sulfathiazole was administered by mouth, and a high blood level maintained.

By next morning improvement was evident. He could speak phrases of several words, and strength began to return in the right hand. It could then be discerned that agraphia was present. The wound healed *per primam.* Headaches gradually disappeared. When evacuated five weeks later there had been marked recovery of

strength as well as in his ability to speak, read, and write. The flap was soft and pulsated well. Papilledema, though still visible, was subsiding.

In contrast to the very satisfactory result of careful secondary débridement, performed 20 days after injury in the above case, the tragic effect of incomplete operation is shown in the next patient:

Case 8.—A 23-year-old male was struck by several shell fragments in the left occiput, right thigh and foot, at 1700 hours, October 13, 1943, in the Volturno River fighting. At an Evacuation Hospital the thigh and foot wounds were débrided and the tiny occipital wound covered with a dry dressing. On board a hospital ship, nine days later, he had a brief attack of meningitis, gram-positive diplococci having been found in the cerebrospinal fluid. When admitted to the Head Center, 11 days after wounding, he was alert, coöperative, and in good general condition. Cervical rigidity had disappeared, and he had no complaints. In the left occipital region there was an unhealed wound, approximately 2 cm. in diameter, which pulsated freely. The skin in this region was thin and depilated from a childhood burn. The thigh and foot wounds were of minor nature and healing well. No papilledema was present, but right homonymous hemianopsia was demonstrable. Vertical and horizontal nystagmus were noted in all ranges except directly forward and downward, the quick-component having been to the right. Deep reflexes were slightly more active on the right, and right leg movements were not as well coördinated as the left. No other neurologic changes were found. Roentgenograms of the skull disclosed extensive fracture with fragmentation in the left parieto-occipital region, and numerous indriven bone chips. A cluster of these lay about 2 cm. beneath the bony defect. A metallic foreign body, approximately 6 mm. in diameter, was visible in the left side of the posterior fossa, apparently lying against the medial end of the petrous pyramid. A second tiny metallic foreign body was observed 4 or 5 cm. beneath the wound. No bone chips were visible in the posterior fossa.

On November 9, 1943, he complained of headaches, and very early papilledema was observed in the left eye. The wound pulsated as before, but hemianopsia was more nearly complete. For the first time, some clumsiness appeared in the left arm, and in both lower extremities. Deep reflexes were equally active, no pathologic reflexes having been found. There was no fever nor cervical rigidity. Sulfathiazole therapy was given and an adequate blood level continuously maintained.

First Operation.—November 10, 1943 (31 days after injury): The bony defect was exposed under novocaine anesthesia through a vertical incision. A well-encapsulated abscess was found containing in its walls the cluster of bone chips, seen by roentgenogram. The cavity extended from the dural opening almost to the tentorium. It was thoroughly emptied of both pus and bone particles. A deep extension was sought for, but not found. A small Penrose drain was left within the cavity for 48 hours.

The wound healed promptly. During the succeeding ten days the patient appeared much improved, bright, cheerful and in no pain. On November 20, 1943, however, headaches reappeared, this time more severe, and accompanied by vomiting. Nystagmus, which had been continuously present, became more marked, while ataxia of the left arm and leg were conspicuous. Pulsation over the skull defect ceased. Restudy of the roentgenograms disclosed that the metallic foreign body in the posterior fossa had rotated between the taking of the successive pictures. This was interpreted to mean that it lay in a fluid medium. Obviously not being in the fourth ventricle, this could but confirm a belated diagnosis of left cerebellar abscess.

Second Operation.—November 21, 1943: Under endotracheal ether anesthesia, small left suboccipital opening was made, 3.5 cm. beneath the dura, an abscess was evacuated, containing 40–50 cc. of pus, from which *aerobic nonhymolytic Streptococci* were subse-

quently cultured. No abscess capsule was palpable. Repeated attempts to grasp the shell fragment were unsuccessful, and eventually abandoned. A small Penrose drain was left in.

Again, relief was but temporary. Two days later signs of rapidly mounting intracranial pressure led to reéxploration of the occipital lobe abscess, the cavity of which contained little or no pus. Once more, the cerebellar abscess was entered, and from 10

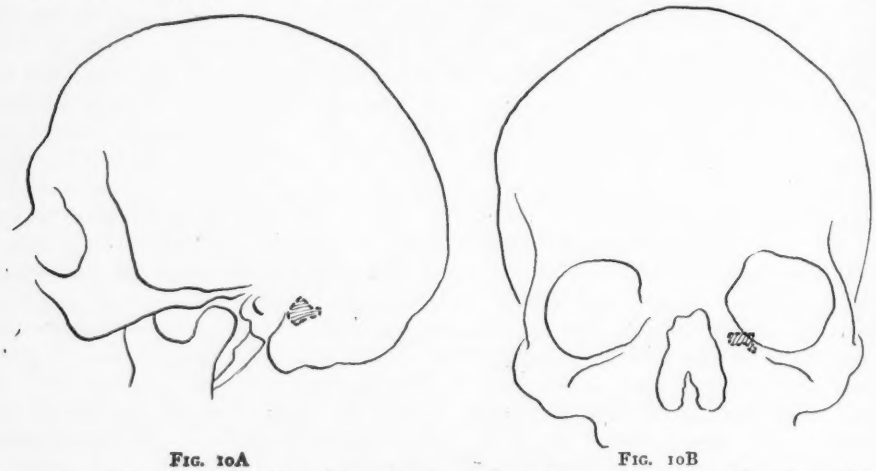


FIG. 10A FIG. 10B

FIGS. 10A and B.—Case 8: Tracing of lateral and anteroposterior roentgenograms. Note the position of the shell fragment in the posterior fossa.

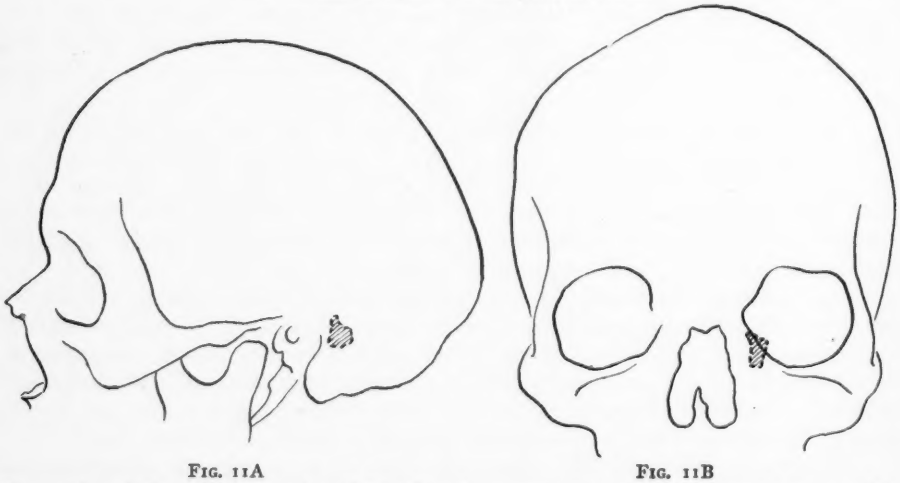


FIG. 11A FIG. 11B

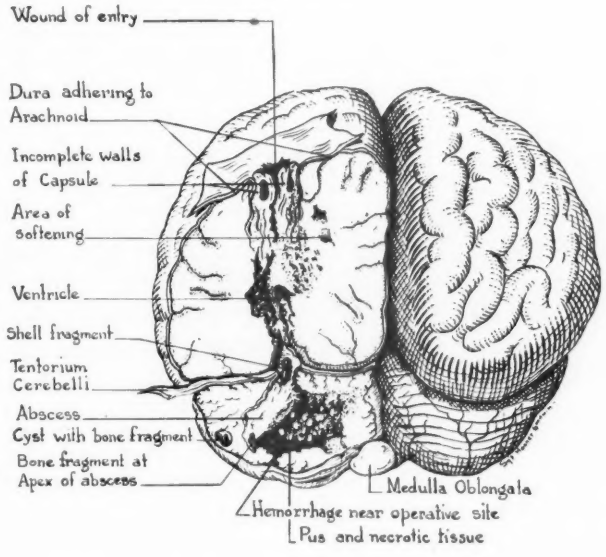
FIGS. 11A and B.—Case 8: Tracing of lateral and anteroposterior roentgenograms showing rotation of shell fragment in the cerebellar abscess.

to 15 cc. of pus and some necrotic tissue were removed. Another attempt to grasp the elusive shell fragment failed—as did a magnet, then employed. He died on November 24, 1943, 42 days after injury.

Postmortem examination revealed a hole in the tentorium which opened directly into the large abscess cavity in the left cerebellar hemisphere (Fig. 12). The larger shell fragment was found at this point. Encapsulation of the abscess was, as may be seen in the drawing, very incomplete. The walls were shaggy with necrotic tissue. Near the bur-hole was some recent hemorrhage. One tiny bone fragment was found in the abscess wall, while a second was nicely encapsulated just beyond. The occipital lobe abscess had collapsed, and was healing. Long strands of fibrous tissue entwined about

the tract of the missile from the dural opening to the tentorium. An area of softening lay medially. The second small metallic foreign body was found well encapsulated. The occipital horn of the ventricle was intact. Meningitis had not developed.

COMMENT.—Had the occipital lobe wound been débrided early, infection there might well have been avoided. Whether or not the cerebellar abscess would have then developed is problematical, since the metallic foreign body



SCHEMATIC DRAWING SHOWING ENTRANCE AND TRACK OF SHELL FRAGMENT

FIG. 12.—Case 8: Combined occipital lobe and cerebellar abscesses, the former healing following evacuation. Metallic foreign body and a small bone fragment lie free in cerebellar abscess. Encapsulation is incomplete in the cerebellum.

might have been responsible. Débridement of the cerebellar wound through the occipital defect seemed hardly feasible. Indeed, this procedure would not ordinarily have been called for since in but three instances was a metallic foreign body found within an abscess; in all others they were clearly sealed-off in their own scar tissue capsules. Doubtless some will later give trouble, but if at this time one attempted to remove all metallic foreign bodies in the brain, much more harm than good would be done. In retrospect, it would appear that our vain efforts to remove this relatively inaccessible shell fragment negated the benefits of evacuating the abscess. Perhaps, had penicillin been available, its use, both locally and generally, might have saved the day. At least, drainage failed to do so!

Treatment of Wound Infection Complicated by Cerebral Fungus.—This was varied according to whether the latter was associated with relatively localized encephalitis, or with, in addition, an abscess. Five of the ten cases in this series fell into the former category. In each the fungus grew slowly. In only two did it become large, fungating, and require excision. The other three regressed spontaneously, without any special treatment other than

general sulfonamide therapy. A sixth patient developed meningitis, but recovered under drug therapy alone. (The causative organism could not be identified in this case, since at that time the laboratory had not begun to function.) A seventh patient with a huge left frontal fungus, extruded a deep abscess, capsule and all, as it was being débrided, and thereafter made an uneventful recovery. The infection in this instance was mixed, both *aerobic hemolytic Streptococcus* and *aerobic hemolytic Staphylococcus albus* having been identified. The three patients who succumbed were admitted during the Salerno fighting, with far advanced infections. In two, the fungus involved the left frontal lobe, while the left parietal lobe was affected in the third. Each was associated with an abscess which was either not found or if so, evacuated too late. Meningitis followed intraventricular rupture of the abscess in two instances, while in the third the ventricle ruptured externally through the extruding fungus.

Dispositions.—Of the 95 surviving patients, 23 were returned to duty in this theater, while the remainder, 72, were evacuated to the Zone of the Interior for further treatment and disposition. The principal factors causing this latter classification were: the cranial defect, the neurologic changes and the associated injuries (see Table V). More than one of these factors were frequently responsible. Reclassification was necessary in 38 patients because of the skull defects alone. It is quite likely that the number eventually returned to duty will be appreciably greater after cranioplasty and recovery from certain of associated injuries. Actually, if appropriate materials were at hand, many skull defects which necessitated reclassification could have been repaired here.

SUGGESTIONS FOR THE EARLY MANAGEMENT OF HEAD INJURIES

As soon as practicable after wounding the scalp should be shaved for at least three inches about the wound, and washed with soap and water. Sulfonilamide crystals may be lightly sprinkled on, and an ample dressing securely applied. Blood loss, shock, and associated injuries require treatment priority according to their severity. Head injuries usually travel well preoperatively, although this is not invariably the case. The patient should be evacuated as directly as possible to a hospital in which deliberate neurosurgery can be performed. The care with which initial débridement is done has much to do with the eventual outcome. Should either surgeon or proper facilities be lacking, further evacuation is preferable to poor débridement.

SUMMARY AND CONCLUSIONS

One hundred cases of compound, comminuted fractures of the skull produced by missiles have been analyzed. More wounds were caused by shell fragments than by all other means. Inner table fractures were sometimes overlooked and occasionally led to serious complications. Tripod incisions often gave trouble; it is recommended that they be avoided when possible. Convulsions were uncommon in the first few weeks; their occurrence was sometimes an early manifestation of abscess formation. Subdural hematoma was present in but two cases. Nineteen patients developed super-

ficial wound infections of varying degrees, while in 22 the infections were deep-seated. These were manifested by abscess, meningitis, cerebral fungus or some combination thereof. There were five deaths, all of which occurred in the latter group.

TABLE V

DISPOSITIONS

To: Class A. (full duty)		3
Class B. (limited duty)		20
Class C. (returned to the Zone of the Interior for further treatment and disposition)		72
Died		5
Total		100
Classified C, because of skull defect alone	19	
Classified B, because of skull defect alone	19	
Total reclassification due to skull defect alone	38	
Total number in which skull defect was a factor		81
Total number in which neural damage was a factor		38
Total number in which associated injuries were factors		23

Incomplete débridement was the largest single factor contributing to wound infection. In those cases in which all bone fragments had been removed, infection was uncommon and seldom deep, whereas, if débridement had been incomplete or not performed at all, infection was common and usually deep. Bacteria cultured from these wounds were principally skin inhabitants of low virulence.

Treatment consisted in evacuation of pus and removal of associated bone fragments and/or metallic foreign bodies, as well as of adjacent necrotic tissue and old blood. Abscess capsules were disturbed as little as possible. Sulfonamide therapy was employed as an adjuvant. Failures resulted only in those five cases in which, for one reason or another, this procedure was not carried out.

Experience, judgment, and skill, as well as proper neurosurgical armamentarium are prerequisite to good primary débridement. It is recommended, therefore, that patients with severe head wounds be evacuated as directly as possible to a hospital in which these are available, even though a few additional hours be required.

ADDENDUM: Following submission of this paper in April, 1944, the number of penetrating wounds of the skull treated in the Mediterranean Theater of Operations has increased several fold. Figures based upon 974 cases from the Tunisian, Sicilian, and Italian Campaigns show the incidence of deep infection to have been 12.2 per cent. During the past year in particular, débridements have been carried out with more thoroughness. Penicillin therapy (25,000 units intramuscularly every three hours) has been routine. The rate of deep infection has been further reduced.

THE SURGICAL MANAGEMENT OF COLON AND RECTAL INJURIES IN THE FORWARD AREAS

MAJOR LAWRENCE E. HURT, M.C., A.U.S.*

THIRTY-NINE battle casualties sustaining injuries of the colon and rectum were operated upon initially by a general surgical team of an auxiliary surgical group functioning with the Fifth Army in Italy. Surgeons engaged in the initial management of intra-abdominal war injuries, particularly colon injuries, are cognizant of the fact that many patients fail to survive. Ogilvie[1] reported 107 injuries of the colon with 63 deaths. In a previous article, using a larger series of cases operated upon by surgeons of our group, the author[2] attempted an appraisal of numerous factors that exerted considerable influence upon mortality. Some of these factors were time-interval between wounding and operation, concomitant wounds, varying degree of peripheral circulatory collapse, and types of operations performed. During the past two years an intensive and comprehensive effort has been put forth by surgical consultants and surgeons in order that an effective decrease in mortality might be obtained in all war injuries. The purpose of this article is to present a brief description of those methods of management employed in a theater of war, and their application to the initial surgery of 39 injuries of the colon and rectum.

Colonel Edward D. Churchill,[3] Theater Consultant in Surgery, has suggested that the surgical care of a severely wounded soldier be divided into three phases—initial, reparative, and reconstructive.

For clarity, it is well to explain that the initial surgery of these colon and rectal injuries was performed in Field Hospitals. The "first-priority" surgical hospital (a platoon of a Field Hospital) is located in physical conjunction with the Division Clearing Station at the rear of the Division boundary. A platoon of a Field Hospital is a small mobile hospital under tentage, having a bed capacity of 30, which can be increased rapidly to 50, or more. It is divided into four sections—resuscitation, X-ray and small laboratory, surgery and surgical supply, and postoperative. When functioning under average conditions, each section can be adequately housed in a ward tent. Essential items of equipment necessary for the performance of major surgical procedures are provided. Administrative and departmental duties commensurate with the successful operation of a hospital are performed by the assigned personnel of the platoon. All professional duties, that is, resuscitation, surgery, and postoperative direction are performed by attached personnel. The attached personnel are members of general surgical and shock teams of an auxiliary surgical group—usually four or more teams depending on the demand and the tactical situation. A general surgical team consists of three medical officers—a general surgeon, an assistant surgeon, and an anesthetist, a surgical nurse and two enlisted men trained as surgical technicians.

* Surgeon, General Surgical Team, 2nd Auxiliary Surgical Group.

Patients not considered "first-priority" are transported from the clearing company to the evacuation hospital usually located five to 15 miles to the rear. The reparative phase of surgery is ordinarily a function of fixed hospitals located in the zones of communication. Those patients requiring reconstructive surgery over a prolonged period of time are evacuated to the Zone of the Interior (Z. I.) that is, the United States or the United Kingdom.

All of the patients underwent initial surgery during the Italian Campaign between the dates of October 1, 1943, and October 15, 1944. This series represents 39 unselected and consecutive hospital admissions sustaining colon and rectal injuries seen by a general surgical team of an auxiliary surgical group. All patients irrespective of multiplicity and severity of wounds, long time-interval, or severe peripheral circulatory collapse were given the benefit of surgery after maximal resuscitation. Most of the casualties were American soldiers. The remainder were British, French Colonials, and German prisoners of war. The youngest patient was 18 years of age, while the oldest was 38. The average age was 25 years.

Before proceeding further, the author wishes to offer an explanation for any statements that might be interpreted as original or positive. In the absence of complete works of reference, many statements are based upon the experience of surgical consultants and surgeons participating in this work.

WOUNDING AGENTS AND TIME-INTERVAL

Most enemy weapons encountered by soldiers of this theater employ the high explosive principle of fragmentation. The fragment wounds were caused by either artillery and mortar shells, grenades, antipersonnel bombs or mines. These agents frequently produced multiple severe wounds. Some of the concomitant wounds were intrapleural injury, traumatic extremity amputation, and compound comminuted fractures of the skull, long bones, and pelvis. Early, many of these concomitant wounds were complicated by hemorrhagic and traumatic shock, and, in some instances, followed by a long period of sepsis. Wounds caused by rifle, machine gun and machine pistol fire are usually single, and occurred in the ratio of approximately one to three, as compared to fragments (Table I).

TABLE I

WOUNDING AGENTS

Agents	No. of Cases	Per Cent
Fragment	30	76.9
Bullet	9	23.0

The time-interval is the time in hours that elapses between wounding and operation. The shortest time-interval was four hours while the longest was 102 hours. The average time-interval was 15 hours (Table II).

A short time-interval is desirable, particularly in the presence of increasing peritoneal contamination and continuing hemorrhage. In our experience, a

TABLE II

TIME-INTERVAL—WOUNDING TO OPERATION

Time in Hours	No. of Cases	Died	Per Cent
0– 6	5	2	40.0
6–12	20	5	25.0
12–18	6	2	33.3
18–24	1	1	100.0
Over 24	7	3	42.8

Average time-interval—15 hours.

short time-interval has not contributed materially toward a decreased mortality in intra-abdominal injuries because some of the most severely wounded came to surgery who would have died had the time-interval been longer.

SHOCK—RESUSCITATION THERAPY—PREOPERATIVE PREPARATION

For the surgeon working in forward hospitals, battle casualties offer inexhaustible opportunities for observing hemorrhagic and traumatic shock, with varying degree of peripheral circulatory failure. For convenience, shock has been arbitrarily classified as suspected, moderate, and severe. This classification was prepared from recorded blood pressure, pulse, color, extensiveness of wounds and condition of the skin. Blood pressure was the most consistent recorded finding. Those patients with a systolic pressure of 100 mm. Hg. plus were put in the suspected group. In our experience, this group of patients developed varying degree of peripheral circulatory failure during surgery whenever preoperative resuscitation was omitted. Those exhibiting a systolic pressure between 80 and 100 mm. Hg. were put in the moderate group and those between 0 and 80 mm. Hg. in the severe group. Certainly, errors in classification have occurred, particularly in the suspected and moderate groups. For example, a patient might have been admitted in incipient hemorrhagic and traumatic shock with a systolic pressure in excess of 100 mm. Hg. and yet he was put in the suspected group. Of 39 patients, 12 arrived at the hospital in suspected hemorrhagic and traumatic shock (Table III). Two of the 12 patients died; one of bilateral lobar pneumonia on the seventh postoperative day and the other of peritonitis on the tenth postoperative day. Ten of the 39 patients fell into the severe group. Eight of the ten patients failed to survive the initial phase of surgery in spite of vigorous replacement therapy.

TABLE III

DEGREE OF SHOCK IN RELATION TO TIME ELAPSED BETWEEN WOUNDING AND HOSPITAL ADMISSIONS—DEATHS

	Hours						
Degree of Shock	0–6	6–12	12–18	18–24	Over 24	Total Cases	Died
Suspected	1	8	1	—	2	12	2
Moderate	3	9	2	—	3	17	3
Severe	1	3	3	1	2	10	8

The majority of patients in severe shock responded within a three-hour period to 2,000 cc. of whole blood, as indicated by a restored systolic blood

pressure of or above 100 mm. Hg. Those patients whose response was slow, or *nil,* received 2,500 to 4,500 cc. of blood within three hours. Five of the eight patients died within the 24th postoperative hour of peripheral circulatory collapse. This observation only confirms the substantiated fact that simple restoration of effective blood circulatory volume does not necessarily alleviate peripheral circulatory collapse. Three patients died after the 24th postoperative hour. Sepsis was the dominant cause of death in this group.

Most plasma was administered before the patient arrived at the hospital. Whenever possible, blood was used to elevate the lowered circulatory volume (Table IV). The total volume of blood administered was approximately three times that of plasma.

TABLE IV

UNITS OF PLASMA AND BLOOD USED IN RESUSCITATION

Agent	Rgt. Colon	Transverse	Left	Rectum	Total Cases	Total Units	Average
Plasma	27	7	31	9	30	74	2.4
Blood	45	13	57	14	37	129	3.4

One unit of plasma is equivalent to 250 cc.
One unit of blood is equivalent to 500 cc.
Maximum units of plasma to one patient were six.
Maximum units of blood to one patient were nine.

Immediately after admission to the hospital, the patients were examined by the resuscitation officer and, as soon as possible, by the surgeon and assistant surgeon. The patients admitted in severe shock were given low titer "o" blood rapidly until cross-matching was completed, and oxygen by mask. As soon as the patients exhibited a favorable response to resuscitation therapy, other preoperative measures were instituted. These measures consisted of nasogastric intubation, urinary bladder catheterization for possible genito-urinary tract damage, and skin preparation. Nasogastric intubation is most important since aspiration of vomitus into the respiratory tract during anesthesia might suddenly, or eventually, become disastrous. It has been our policy to pass the Levine tube into the stomach, and, if the gastric contents was free of macroscopic blood, moderate gastric lavage was performed before the induction of anesthesia.

INJURIES OF THE COLON AND RECTUM

All injuries of the colon included in this series resulted in fecal peritoneal contamination of varying degree. Intraperitoneal injuries of the rectum were placed in the colon group. All of the injuries in the rectal group were extraperitoneal.

The types of colon injuries were single or multiple mesenteric, lateral, and antimesenteric perforations; hemisection; transection; and longitudinal tears. Contusions, lacerations not involving the mucosa, injuries to the mesocolon interfering with blood supply, and posterior wall perforations without peritoneal soiling were not included.

Table V is included to emphasize a moderately high incidence of injury to certain related viscera. Some of the factors that determined the likelihood

of injury to related viscera were: Location of the wound of entry; size, contour, and velocity of the missile; and the surface area of the related viscus. The influence of a vast surface area was corroborated by the fact that 13 of the 39 patients sustained injury to the small bowel.

TABLE V

INCIDENCE OF INJURY TO RELATED VISCERA

	No. of Cases	Small Bowel	Liver	Diaph.	Stomach	L. Kid.	R. Kid.	Spleen	Bladder	2nd Part of Duodenum
R. C.....	14	3	1	1	—	—	1	—	—	2
T. C.....	4	1	1	3	3	—	—	1	—	—
L. C.....	15	8	2	1	—	2	—	1	—	—
Rectum.....	6	1	—	—	—	—	—	—	3	—

Five of the 33 colon injuries were complicated by injury to the diaphragm: that is, they were thoraco-abdominal wounds. The second part of the duodenum was involved in two of four cases with injuries of the hepatic flexure. Such a high incidence necessitates exposure of this part of the duodenum whenever the hepatic flexure is injured.

ANESTHESIA

Ether, open-drop or in a closed system, was used for all operations. Among the anesthetic agents used for induction, excluding ether, were nitrous oxide-oxygen and ethyl chloride. Nitrous oxide-oxygen-ether, using the closed absorption, endotracheal technic was the most frequently used anesthesia. Endotracheal anesthesia was employed in all thoraco-abdominal and separate intrapleural injuries.

TYPES OF OPERATIONS PERFORMED UPON THE COLON AND RECTUM

For obvious reasons, primary suture of the unprepared colon in the presence of peritoneal contamination has always been condemned in this theater. Consequently, all initial operations were designed to divert the fecal current outside the peritoneum. The only exception to this rule has been in those patients sustaining injury between the sigmoid and the extraperitoneal rectum. These perforations were closed by suture and supplemented by proximal colostomy (Table VI). The type and severity of the injury occurring between the terminal ileum and sigmoid colon usually determined whether a loop or double-barrel colostomy with spur was to be performed. Single or closely associated multiple anterior and lateral wall perforations and antimesenteric hemisections were exteriorized as loop colostomies. Mesenteric hemisections, transections, and extensive injuries necessitating resection of the colon were exteriorized as double-barrel with spur colostomies. We have endeavored to perform an initial operation that not only diverts the fecal current extraperitoneally, but also leaves the patient with a simple stoma which can be closed secondarily without entering the peritoneal cavity. Since the extraperitoneal closure of a loop colostomy of the right colon is impractical, a single perforation of the right colon was treated by tube colostomy or cecostomy. The tube and about two centimeters of adjacent tissue around the tube were extraperitonealized through a stab

incision to prevent any subsequent leakage into the peritoneal cavity. At secondary operation, this extraperitonealized portion of colon could be utilized to close the colonic fistula without entering the peritoneal cavity. Three patients were treated successfully by this procedure.

TABLE VI

TYPES OF OPERATIONS PERFORMED ON THE COLON AND RECTUM

Type of Operation Performed	Right Colon	Left Colon	Trans. Colon	Rectum	Total	Deaths	
						Number	Per Cent
1. Exteriorization	4	12	4	—	20	10	50.0
2. Resection of terminal ileum, cecum, ascending colon and double-barrel ileo-transverse colostomy	4	—	—	—	4	1	25.0
3. Tube cecostomy or colostomy	3	—	—	—	3	0	—
4. Resection and exteriorization	—	1	—	—	1	0	—
5. Suture of perforation and proximal cecostomy or colostomy	1	2	—	—	3	0	—
6. Proximal colostomy and coccygectomy	—	—	—	6	6	0	—
7. None (died during surgery)	2	—	—	—	2	2	100.0

Injuries of the splenic flexure and left half of the transverse colon complicated by those of the left diaphragm and left lung caused by a single missile were operated upon transdiaphragmatically. Some of the advantages of a thoracic operative approach in left-sided thoraco-abdominal wounds were: Excellent visualization of the wound tract; easy removal of the frequently fragmented spleen; mobilization of the splenic flexure under direct vision; and the elimination of the separate celiotomy incision, with its subsequent pain, which permitted the institution of an intensive cough routine so necessary for the postoperative intrapleural injury. Before closure of the diaphragm, the injured segment of the splenic flexure or transverse colon was exteriorized either as a loop or double-barrel colostomy with spur through a stab incision in the left upper quadrant of the abdomen. Likewise, if drainage of the abdomen was desired, the drains were brought out through another, but smaller, stab incision of the left abdominal wall. On the contrary, injury of the hepatic flexure complicated by those of the liver, right diaphragm and right lung caused by a single missile necessitated thoracotomy and a separate celiotomy incision, as the liver offers complete obstruction to exploration of the right abdomen.

The initial surgery of extraperitoneal perforations of the rectum consisted of thorough débridement of the wound tract, suture of perforations, and sigmoid colostomy. In addition, resection of the coccyx and incision of the fascia propria were done to insure adequate drainage of the retroperitoneal, posterior, and pararectal spaces. All sigmoid colostomies were of the loop type. However, a recent personal communication with surgeons in Base Hospitals has revealed that loop colostomy for rectal injuries has failed, in many instances, to completely divert the fecal current. Consequently, patients with rectal injuries have arrived at the Base from the Forward Area Hospitals with fecally contaminated buttock wounds, and the rectum filled with feces. In the future, we expect to transect the sigmoid and prepare a spur at the

time of initial operation of all extraperitoneal rectal injuries. Colcock[4] has reported from a hospital in the Zone of Communication that osteomyelitis of the sacrum has been a frequent complication of coccygectomy in those with rectal wounds. Because of this, posterior drainage is now being accomplished without resection of the coccyx. It is the feeling of most of our surgeons that adequate drainage can be ensured through a curved incision inferior to the coccyx; incision of the fascia propria; and opening of the posterior and pararectal spaces by blunt dissection.

USE OF SULFONAMIDES AND PENICILLIN—POSTOPERATIVE CARE

The methods of administration and dosage of sulfonamides, according to a suggested regimen developed by Theater and Army Consultants for the guidance of Forward Area surgeons, were constant throughout the entire series of cases. An amount not exceeding 10 Gm. of sulfanilamide per patient was used at operation. Five grams were dusted into the peritoneal cavity before closure of the abdominal wall. The remaining 5 Gm. were dusted into, and distributed proportionately, among the operative sites of concomitant wounds. Consequently, those patients sustaining only an intra-abdominal injury received 5 Gm. of sulfanilamide at operation. Intravenous sodium sulfadiazine was started 24 hours after operation in the dosage of 2.5 Gm. every 12 hours until the patient could tolerate 1 Gm. orally every four hours. Therapy was continued from five to seven days and longer, if indicated. The only exceptions to this rule were two patients whose urinary output did not exceed 1,200 cc. daily, in spite of an adequate fluid intake.

Penicillin for routine use in intra-abdominal injuries was available for only the last ten of the 39 patients. Twenty-five thousand units of penicillin in 10 cc. of distilled water were injected into the peritoneal cavity in conjunction with 5 Gm. of sulfanilamide before closure of the abdominal wall. Postoperatively, 25,000 units of penicillin were administered intramuscularly every three hours for five days, and longer, if indicated. Five of the ten patients died—four of sepsis and one of anuria. Therefore, in this small series of cases, there was no evident reduction in mortality as compared to that when sulfonamides were used alone.

Postoperative care consisted of skilled nursing, correction of protein and vitamin depletion, and the utilization of specific measures to combat shock and infection. A lowered protein intake combined with the additional loss from hemorrhage, and a lowered vitamin intake were responsible for protein and vitamin depletion. Plasma and blood were administered to elevate the blood proteins and the lowered circulatory blood volume. To insure an effective vitamin "C" level, ascorbic acid was given intravenously until polyvitamins could be tolerated orally. Hydration and nutrition were maintained by the daily administration of 3,000 cc. or more of 5 per cent glucose in normal saline. Ileus and abdominal distention were controlled by nasogastric suction. In the absence of marked peritoneal infection, delayed colostomy function was initiated by the installation of 30 cc. of mineral oil

into the proximal loop of the colostomy on the fourth or fifth postoperative day.

COMPLICATIONS

Shock and infection were the dominant complications. Most patients admitted in suspected, or a moderate degree of shock, responded favorably to blood and plasma replacement therapy during resuscitation, operation and the postoperative period.

Peritoneal contamination and early infection responded gratifyingly to forward surgery and its adjuncts, sulfonamides and penicillin, for only 12 of the 33 intra-abdominal injuries exhibited objective signs of peritonitis. We have attributed our low incidence of pulmonary complications to routine postoperative bronchoscopy and catheter suction of the trachea of all intra-abdominally injured patients sustaining concomitant intrapleural injury or possessing excessive tracheobronchial secretion. Five of the 33 intra-abdominal injuries developed severe infection of the celiotomy incision, although colostomies were placed in separate incisions. None of the wound infections led to dehiscence. Other complications recorded during the postoperative period are listed in Table VII.

TABLE VII

COMPLICATIONS

Complications	No. of Cases	Died
Peritonitis	12	2
Pneumonia	5	2
Atelectasis	2	0
Shock (severe)	8	5
Severe infection of celiotomy incision	5	0
Anuria	2	2
Shock and peritonitis	2	2

MORTALITY

Thirteen of the 39 patients died—a mortality rate of 33.3 per cent (Table VIII). Injury to the colon or rectum alone occurred in eight of the 39 cases. Five of the eight patients sustained injuries of either the right,

TABLE VIII

MORTALITY

	No. of Deaths	Per Cent
Right colon	6	42.8
Transverse colon	2	50.0
Left colon	5	33.3
Rectum (extraperitoneal)	0	—

Total deaths.....13 Mortality rate.....33.3%

transverse, or left colon, and three of the extraperitoneal rectum. All of these patients survived, and were evacuated to the Zone of the Interior on an average of 65 days after initial surgery. The remaining 31 cases were complicated by concomitant wounds varying in severity from mild soft-tissue wounds to such severe injuries as small bowel transections, necessitating two small bowel resections; kidney fragmentation; liver perforation, compound

comminuted fractures of the skull, pelvis and long bones; intrapleural injury; and traumatic extremity amputation.

Two patients died during surgery. Both were admitted to the hospital with a long time-interval; septic from a generalized peritonitis; and in severe peripheral circulatory collapse. Both responded very poorly to resuscitation therapy. In our experience, all battle casualties presenting a picture of sepsis and profound peripheral circulatory collapse tolerate anesthesia and surgery very poorly, and are obviously designated "bad risks."

Two deaths on the eighth postoperative day were attributed to uremia. Both presented evidence of urinary suppression at the end of the first postoperative day, which gradually increased until death. They were admitted to the hospital in severe peripheral circulatory collapse and given either low titer "o" or cross-matched blood during resuscitation and surgery.

Bilateral lobar pneumonia was responsible for two deaths. Their injuries were of the thoraco-abdominal type, with the pneumonic process involving first the injured lobes and, later, the lobes of the contralateral lung.

Five of the 13 deaths occurred during the first postoperative day. All failed to respond to quantities of blood up to 4,500 cc. administered during the resuscitation, operative, and postoperative periods. The 12th and 13th deaths were due to generalized peritonitis. One of these died on the ninth postoperative day, and the other on the 12th postoperative day.

Detailed information concerning the reparative phase of surgery of the 26 surviving patients was obtained by communication with the office of the Base surgeon and surgeons of Station and General Hospitals located in the Zones of Communications. All of the patients were evacuated to the Zone of the Interior on an average of 65 days following initial surgery.

We have not obtained any information concerning the patients after their arrival in the Zone of the Interior.

SUMMARY

Initial surgery of 39 injuries of the colon and rectum was performed by a general surgical team of an auxiliary surgical group functioning with the Fifth Army in Italy. Most of the injuries were caused by fragments. Twenty-nine patients were operated upon within 12 hours of injury; five within six hours. A short time-interval can contribute toward an increased mortality, because more of the severely wounded come to surgery. The average time-interval was 15 hours. The contribution of shock toward an increased mortality was exemplified by five deaths, in spite of vigorous replacement therapy, out of eight patients admitted in severe shock. The second part of the duodenum was injured in two of four injuries of the hepatic flexure. Peritoneal contamination and early infection responded gratifyingly to Forward surgery and its adjuncts, sulfonamides and penicillin, for only 12 patients exhibited objective signs of peritonitis. Eight patients sustaining injuries of the colon or rectum alone were treated successfully. Thirteen colon injuries complicated by severe concomitant wounds died—a

mortality rate of 33.3 per cent. Severe shock, secondary to injuries of the colon complicated by concomitant wounds, was the dominant cause of death. Next to shock, sepsis was the leading cause of death.

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THE MANAGEMENT OF WAR INJURIES OF THE EXTRAPERITONEAL RECTUM

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INJURIES OF THE RECTUM present many problems which are peculiar to it alone. These problems arise largely from its physiologic and anatomic properties. As the organ of temporary storage and evacuation of the solid wastes of the intestinal tract, its contents teem with organisms, many of them potential pathogens, both aerobic and anaerobic. Anatomically, it is for the most part unprotected by infection-resisting peritoneum. It traverses a tissue which is highly vulnerable to infection, and it is difficult of surgical access. In order to understand more fully the implications of the anatomic problems, let us examine some of the essential details of the relationships of the rectum.

The rectum, the terminus of the large bowel, is arbitrarily said to begin at the level of the third sacral vertebra and end in the anal canal (Fig. 1). Its average length is 12 cm. The lateral and anterior surfaces of the proximal portion, 5 cm. in the male, 7 cm. in the female, are invested with peritoneum. The posterior surface of this proximal portion is retroperitoneal, the distal portion is infraperitoneal. The rectum ending below at the level of the internal sphincter to become the anal canal, is approximately 2 cm. long and is circumvested by the external sphincter. The internal structure of the pelvic floor, through which the rectum passes, may be likened to a trough, the sides of which are formed by the levators ani and coccygei, flat, sling-like muscles originating from the internal surfaces of the pelvis on either side, from the pubic tubercle in front to the coccyx behind, to join in a median raphe below. The triangular anterior wall is formed by the urogenital triangle, while the triangular posterior wall is formed by the sacrum and coccyx. Through this trough-like space descend the rectum posteriorly and the urogenital tract anteriorly. Over this trough-like space and its viscera, the peritoneum is loosely draped as a cover. Actually, this space is more potential than real, since it is filled with a cellular areolar tissue. This space is, therefore, bounded laterally by the levators, inferiorly by their raphe, anteriorly by the urogenital triangle, posteriorly by the sacrum and coccyx and superiorly by the peritoneum, and will be referred to as the infraperitoneal space. When this space is distended by pus or blood, its expansion is found to be definitely limited in certain directions, relatively unlimited in others. Rigid fascial planes prevent extension in any direction except superiorly. Laterally, these fascial planes are formed by the medial investment of the levators, the superior levator fasciae. These layers join inferiorly over the raphe, and become continuous at the rectal and urogenital outlet with a similar layer of fascia loosely investing these viscera, the endopelvic fascia. Anteriorly, the superior levator fascia

fuses with the deep layers of the urogenital triangle, and posteriorly, with the periosteal layer of the sacrococcygeal fascia. Expansion of the infraperitoneal space is, therefore, limited inferiorly, laterally, anteriorly and posteriorly by fascial planes, but is relatively uninhibited superiorly by the loose peritoneal roof. Even this, however, is rather firmly adherent laterally along the line of origin of the levators, at the so-called "white line" where levator fascia fuses with the obturator fascia above. Since the peritoneum is most loosely attached over the sacral promontory on either side of the rectum, it is

CORONAL SECTION OF PELVIS

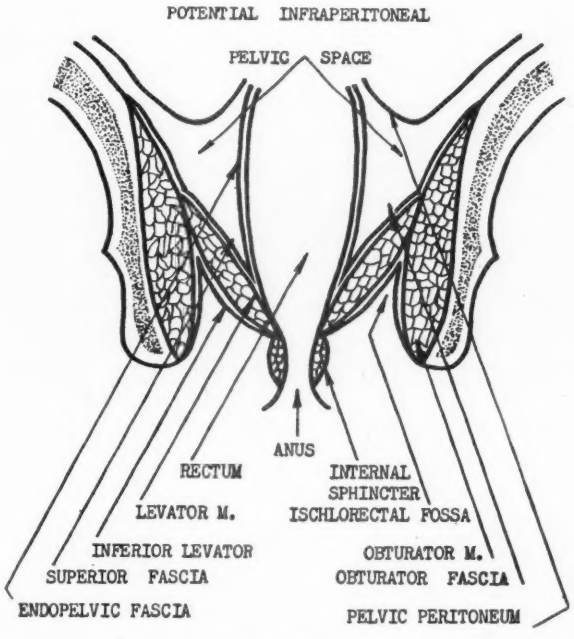

FIG. 1.—Diagram of coronal section of pelvis demonstrating the infraperitoneal space.

here that the infraperitoneal space readily communicates with the retroperitoneal space. When the infraperitoneal space becomes distended with pus or blood, it, therefore, spills through this escape route into the retroperitoneal space. This has been demonstrated experimentally in the cadaver by the serial roentgenologic studies of progressive injection with sodium iodide solution into the infraperitoneal space (Figs. 2 and 3). It is also well illustrated in one of the cases presented below (Case 1).

While perforation of the infraperitoneal portions of the rectum and bladder cause infection of the infraperitoneal and eventually of the retroperitoneal space, perforation of the anal canal causes infection of the ischiorectal fossae on either side. These are symmetrical pyramidal spaces, one on each side beneath the pelvic floor. The medial wall of each space is formed above by the levator and its investing fascia, the inferior levator fascia, and below by

the anal canal. The lateral wall of each is formed by obturator internus and its investing fascia, and the base by the superficial fascia and skin alone (Fig. 1). Expansion of these spaces is limited on all sides except at the base, so that the ischiorectal abscess points at the skin. Again, serial roentgenologic studies of progressive injection with sodium iodide solution of the ischiorectal space in the cadaver illustrates the barriers formed by the pelvic floor between these spaces and the infraperitoneal space (Fig. 4). Extension of infection does not occur from one to the other except by trauma to the levator and to investing fasciae.

The clinical syndrome of retroperitoneal sepsis was a nightmare to the surgeons of World War I.[1, 2] Little was written, and apparently little was known, regarding its prophylaxis or treatment. Drummond reviewed the problem at the close of World War I.[3] His mortality statistics are discouraging: "From the table of gunshot wounds of the rectum there were fourteen deaths out of sixteen cases with two recoveries; seven died from shock, six from retroperitoneal sepsis and one from peritonitis with retroperitoneal sepsis." His clinical description of the acute casualty is borrowed from Fraser[4] and is vividly imaginative. "John Fraser also laid great stress on retroperitoneal sepsis, and applied the term 'colon septicaemia' to a group of symptoms present in cases of colon wounds with a spread of infection to the retroperitoneal tissue." Drummond's suggestions as to treatment reveal that the problem at that time was still very much in the experimental stage, although some of his suggestions have proved extremely practical:

"In extraperitoneal wounds of the rectum the only hope of success lies in very free local drainage carried out at the earliest possible moment. With a view to establishing efficient drainage, I removed in two cases, the uninjured coccyx in addition to free drainage of the wounds of entry and exit, and found by stripping up the bowel that one was able to expose the wound in the rectum and was thus enabled to drain and pack off the surrounding parts and prevent further tracking by retroperitoneal hemorrhage."

During the past two years, we have been fortunate enough to administer definitive treatment to a moderate number of patients returning from the battlefields in various stages of convalescence from war wounds of the rectum. In addition, we have been able to evaluate the treatment of many others who have not remained under our care. From these observations, we feel that progress has been made during this war in the management of extraperitoneal injuries of the rectum. We feel that sufficient progress has been made to warrant crystallization of the surgical management. We wish to emphasize here the part played by surgical prophylaxis in contrast to the supportive measures of blood, plasma, and chemotherapeutic agents. Invaluable as they are, when applied alone, without surgery, they may influence the early mortality rate in assisting recovery from shock, but not appreciably the morbidity or late mortality rate from chronic sepsis. These measures have been proved to be merely adjuvants and not in any way substitutes for early and properly executed surgery.

FIG. 2.—Anteroposterior radiograph demonstrating the extension of the infraperitoneal into the retroperitoneal space by injection of sodium iodide solution into the former space in the cadaver.

FIG. 3

FIG. 4

FIG. 3.—Lateral radiograph as in Figure 2.

FIG. 4.—Anteroposterior radiograph demonstrating the confines of the right ischiorectal fossa after injection with sodium iodide solution in the cadaver.

What, then, is properly executed surgery? Examination of the anatomy of the pelvic floor reveals that a very simple approach to the infraperitoneal space lies posteriorly. Through a midline incision, one may easily expose and excise the coccyx, then incise the precoccygeal fascia and thus expose the areolar tissue of the perirectal space. By loosely packing this space one has provided very adequate dependent drainage well calculated to prevent the spread of infection and development of retroperitoneal sepsis. Moreover, the exposure of the posterior and lateral walls of the lower rectum permits exploration for laceration of the viscus, and an opportunity to suture it. Failure to perform the latter procedure may result in chronic sepsis and retardation of wound healing, and, finally, the establishment of a chronic fistula, even in the presence of a proximal colostomy. However, it is recognized that this ideal may not be attainable at the primary procedure because of the precarious condition of the patient or the pressure of other life-saving measures. Furthermore, even when the patient's condition and other circumstances permit, this ideal may still be unattainable because in many instances the laceration will be inaccessible, in others, it will not be detectable because of hemorrhage in the rectal wall, while in still others, perforation will appear as a result of infarction only several days after trauma.

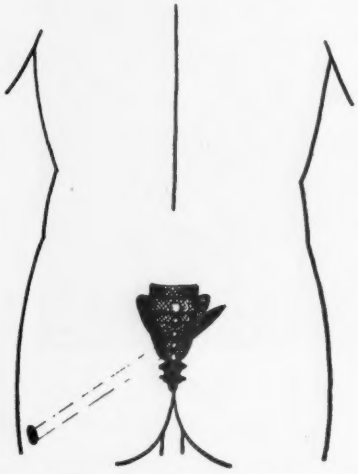

FIG. 5.—Diagram illustrating the course of the bullet. (Posterior view)

We have selected for presentation a number of clinical cases from which we have evolved a rationale of management, and we shall present them below *pari passu* with our observations regarding their contributions to the final plan of management.

CASE REPORTS

Case 1.—A 23-year-old soldier sustained a penetrating gunshot wound of the left buttock in North Africa on March 27, 1943. The bullet perforated the rectum and lodged in the bodies of the first and second sacral vertebrae (Fig. 5). Celiotomy was performed through a lower left rectus incision the following morning. Apparently, no intraperitoneal lesion was found and the wound was closed without drainage and without colostomy. The celiotomy wound became infected, and was widely opened (Fig. 6). Fecal drainage appeared from the wound of entrance in the left buttock. The patient became acutely ill and rapidly malnourished, despite vigorous supportive measures. When he arrived at the Zone of Interior, April 30, 1943, he was severely septic and emaciated. The celiotomy wound was superficially epithelized, with wide musculofascial defect. There was a deep-lying tender mass in the right lower quadrant against the right inguinal ligament. There was frank fecal drainage from the wound of entrance in the lateral aspect of the left buttock, which communicated with a fecal abscess underlying the gluteal muscles. There was a large decubitus ulcer over the sacral region.

On admission, the R. B. C. was 3.29 million per cu. mm., W. B. C., 7,400 cu. mm.; hemoglobin, 12.6 Gm. per cent; uranalysis and Kahn were negative. Roentgenograms revealed a bullet lodged near the right sacro-iliac joint. On May 6, 1943, an attempt was made to improve the drainage of the fecal abscess of the gluteal region. On May 11, 1943, the mass in the right lower quadrant of the abdomen was incised and found to be a fecal abscess. Lipiodol injection of the incision in the right inguinal region revealed a communication with the infraperitoneal space (Figs. 7 and 8). Despite vigorous supportive measures with plasma, blood and sulfonamides, the sepsis and emaciation increased. A barium meal revealed no evidence of an internal fistula involving small bowel or cecum. All the evidence indicated that the fecal abscess in the right inguinal region was an overflow from the infraperitoneal space which was being filled by an infraperitoneal perforation of the rectum (Fig. 9). Therefore, on June 10, 1943, a sigmoid colostomy was performed to divert the fecal stream. There

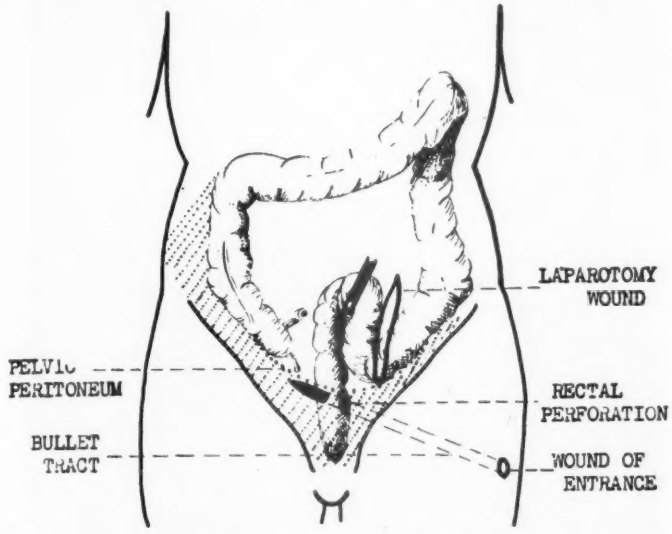

FIG. 6.—Diagram illustrating the infraperitoneal perforation of the rectum and the celiotomy wound. (Anterior view)

was some improvement for a while, but large amounts of malodorous pus continued to discharge from the left buttock and through the right inguinal incision. On August 2, 1943, the discharge from the right inguinal incision again became feculent and it was presumed that an internal fistula had developed with the cecum or ascending colon. Barium studies failed to reveal this internal fistula. On August 9, 1943, the discharge from the right inguinal incision became blood-tinged. The prothrombin time was normal. On August 10, 1943, rather profuse hemorrhage appeared from the right inguinal incision, distal sigmoid colostomy orifice, the rectum and left buttock incisions, and the patient died despite attempts to pack off the vessels through the wound in the right inguinal region, and the use of multiple transfusions.

Autopsy revealed marked emaciation. The peritoneal floor of the pelvic cavity had been raised by the underlying necrotizing infection of the infraperitoneal space. This infection was not only posterior, about the rectum, but had extended anteriorly about the bladder. It communicated with the abscess underlying the left gluteal muscles through the bullet tract in the left levator muscle. There was a perforation of the rectum in its posterior wall about 8 cm. above the anal orifice. The bullet lay embedded in a crumbled mass of cancellous bone of the first and second sacral vertebrae near the sacro-iliac joint just above the peritoneal reflexion. Thence, the fecal abscess had

extended retroperitoneally to the right iliac fossa where it continued to burrow upward along the posterolateral wall of the ascending colon almost to the liver. About midway in the ascending colon, a secondary wide communication had become established with the retroperitoneal space (Fig. 10).

COMMENT: It seems very unlikely that this internal fistula could have been traumatic in origin. In fact, if it had been present prior to establishing the sigmoid colostomy on June 10, 1943, the external fecal fistula in the left gluteal region and the right inguinal region would not have lost their

FIG. 7.—Anteroposterior radiograph after lipiodol injection of right inguinal incision showing upward extension along right iliac fossa and downward to the perirectal space.

fecal characteristics after sigmoid colostomy. It was not until August 2, 1943, that the discharge from these again became feculent and it was then that this secondary communication proximal to the colostomy must have become established. There was a septic erosion of the outer walls of many visceral branches of the pelvic vessels but the exact origin of the hemorrhage could not be located.

This represents a casualty which probably would not have survived more than a few hours were it not for the excellent supportive therapy our soldiers have been receiving at the front—blood, plasma and chemotherapeutic agents. We do not know what the findings were at the time of initial celiotomy except that no intraperitoneal visceral lesion was found. Soon after operation the patient became very ill, and fecal drainage appeared from the wound of entrance. Had a sigmoid colostomy been established at

that time and the infraperitoneal space widely saucerized through coccygectomy, the subsequent course might have been modified. Upon arrival here, the patient was in such poor condition that a major operation did not, at that time, seem feasible. Even diagnostic procedures were exhausting to the patient. From the light of subsequent events, and our observations of similar cases, thereafter, a coccygectomy with widespread saucerization of the infraperitoneal space should have been performed as soon after arrival as possible,

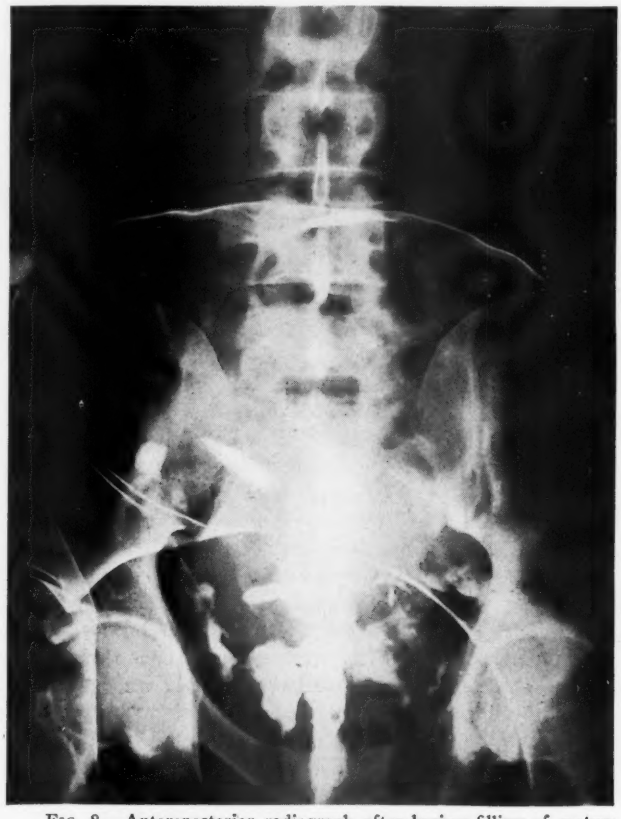

FIG. 8.—Anteroposterior radiograph after barium-filling of rectum showing the extension of barium into the infraperitoneal space and upward toward the right iliac fossa.

together with a sigmoid colostomy. Whether he would have survived such a procedure is problematical, but it would have given him his only chance. Of course, if the internal retroperitoneal fistula into the ascending colon had already been established, even this would have failed, as nothing short of an ileostomy would have diverted the fecal stream, but the evidence indicates that this secondary fistula had not become established until later.

This case, therefore, well illustrates (1) a pathway of spread of infection from the infraperitoneal to the retroperitoneal space. (2) The importance of early surgery for infraperitoneal perforations of the rectum. (3) The futility of supportive treatment in the absence of early surgery. (4) The profound malnutrition resulting from infection of the areolar tissue of the

infra- and retroperitoneal tissues, in the absence of early and adequate drainage.

Case 2.—While in action on the Italian front at 1400 hours on April 3, 1944, a 25-year-old soldier sustained multiple shell fragment wounds of the left lower extremity, the right thigh, the left buttock, and the left forearm. The latter caused paralysis of the radial and ulnar nerves and a compound fracture of the radius. At 0230 hours, the following morning operation was performed under open-drop ether anesthesia. All wounds were débrided. Foreign bodies were removed from the left thigh, left buttock, left arm, left foot and right thigh. The left forearm was immobilized in plaster. Through a lower left paramedian incision, the abdomen was explored. A massive extraperitoneal hemorrhage was found in the pelvis. The peritoneum was reflected, a large shell fragment was removed from the right lateral pelvic wall, and two Penrose drains were inserted extraperitoneally to this site from the lower end of the wound. The surgeon was not cognizant of any rectal perforation at this time and colostomy was not performed. On April 8, 1944, after an enema, feces returned through the wound of the left buttock for the first time, indicating to the surgeon that a contused area in the rectum had sloughed away. A sigmoid colostomy, through a left gridiron incision, was performed without delay, and opened on April 13, 1944. The patient continued to be moderately ill and, April 23, 1944, a left para-anal incision was made through the ischiorectal fossa into the infraperitoneal space, and the sigmoid colostomy completely divided. On May 15, 1944, examination revealed that the lower 6 cm. of the midline celiotomy wound were unhealed and draining pus. Rectal examination revealed a perforation, 3.5 cm. in diameter, in the posterior wall of the rectum, 5 cm. above the anus, communicating with a large perirectal abscess (Fig. 11). It was draining inadequately through a left para-anal incision, so this incision was enlarged. The granulating wounds of the left lower extremity and right thigh were excised and sutured. The patient had had a nonspecific epididymitis which was gradually subsiding. He was evacuated to the Zone of Interior on July 3, 1944.

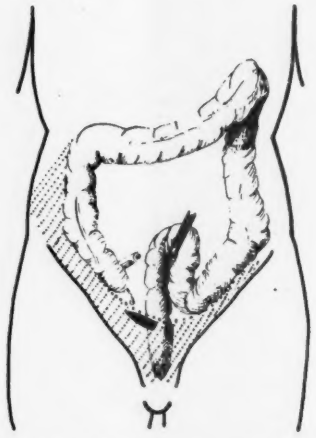

FIG. 9.—Diagram illustrating the extension of the infraperitoneal abscess upward along the right iliac fossa. (Anterior view)

On arrival here, the R. B. C. was 4.7 million per cu. mm.; W. B. C., 6,600 per cu. mm.; hemoglobin, 15 mg. per cent. Uranalysis was negative. Serum protein was 5.7 Gm. per cent. N. P. N., 26 mg. per cent. Despite continued supportive treatment of high caloric diet, vitamins, administration of blood and plasma and later penicillin, the clinical picture remained one of chronic sepsis and its attendant malnutrition. Lipiodol injection of the orifice at the lower end of the celiotomy wound revealed a fistula extending laterally along the right wall of the pelvis, puddling about the lower end of the rectum and finally into the rectum and also out through the left para-anal incision (Fig. 12).

On September 25, 1944, through a midline coccygeal incision the coccyx was resected. On incising the precoccygeal fascia a large perirectal abscess was encountered filled with necrotic and suppurative débris. A large perforation, 3 cm. in diameter, was found in the posterior wall of the rectum. The abscess extended anteriorly on both sides of the rectum, on the right further than could be reached by the finger. The perforation of the rectum was sutured, a cigarette drain placed into each anterior

extension of the infraperitoneal space and the cavity loosely packed. Postoperatively, parenteral penicillin 200,000 units daily was administered.

The patient improved to some extent following this procedure. The suture line closing the perforation of the rectum was soon digested in the infectious process. The cigarette drains in the anterolateral extensions were removed in eight days. The left anterolateral extensions closed completely. The right, which was larger, and was suspected of communication with the caudal end of the abdominal wound by way of the lateral wall of the pelvis, seemed at first to be closing but soon began to drain large quantities of pus. The patient began to complain of pressure pain deep in the perineum. On October 31, 1944, a catheter was introduced into this extension and it was filled with lipiodol and roentgenograms taken (Fig. 13). These films revealed a wide sinus extending along the right anterolateral wall of the pelvis almost to the symphysis pubis.

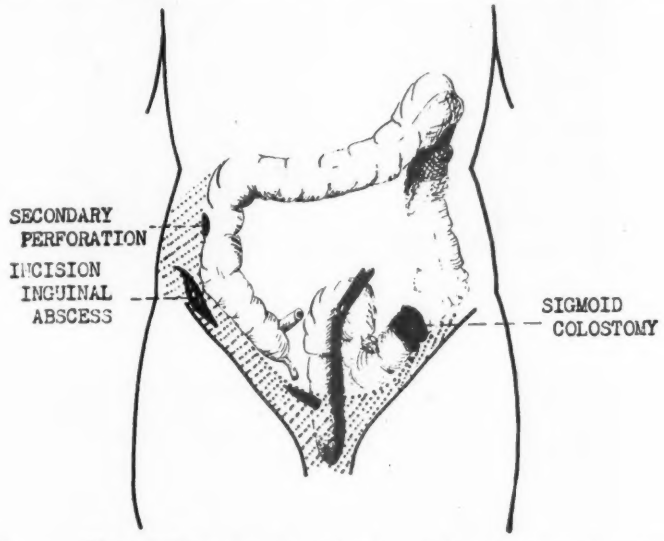

FIG. 10.—Diagram illustrating the perforation of the retroperitoneal surface of the ascending colon proximal to the sigmoid colostomy.

Within this sinus there seemed to be a sequestrum apparently detached from the ascending ramus of the ischium. On November 1, 1944, under intravenous pentothal anesthesia, the sinus was opened widely and the sequestrum removed. No attempt was made to resuture the perforation of the rectum because of the presence of infection. Following this procedure, the infection gradually subsided and the patient's general condition gradually improved.

Once the infection of the infraperitoneal space has been completely controlled, an attempt will be made again to close the perforation of the rectal wall. If this is successful and the posterior wound heals, the colostomy may be closed to reëstablish intestinal continuity.

COMMENT: The ultimate result of this case is expected to be a successful one, but not without great danger and long and serious morbidity. This case differs from Case 1, first, in that colostomy was established as soon as it became clear that an extraperitoneal perforation of the rectum was present, and, secondly, in that some type of drainage of the infraperitoneal space was established immediately after injury, thus, preventing spread in undesirable locations difficult to recognize, and more difficult to reach. However, it

illustrates the inadequacy of draining the infraperitoneal space upward on the anterior surface of the lower abdomen. It, likewise, illustrates the inadequacy of drainage of the infraperitoneal space by a lateral incision

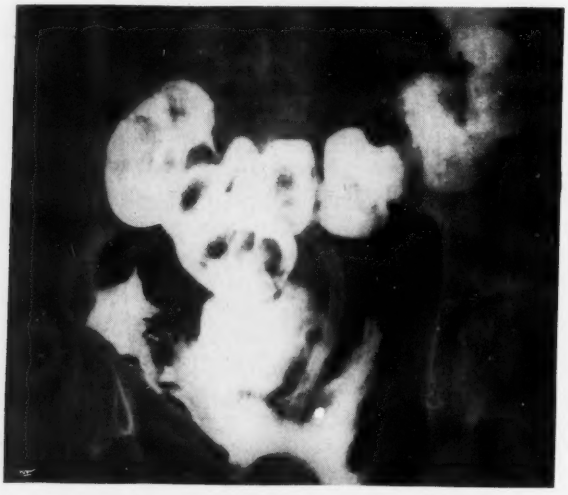

FIG. 11.—Anteroposterior radiograph after barium-filling of the rectum demonstrating the escape of barium into the infraperitoneal space.

FIG. 12.—Anteroposterior radiograph after lipiodol injection of the suprapubic sinus. Note the communication along the right side of the pelvis with the large space anterior to the lower end of the sacrum. The top of the catheter lies in the suprapubic sinus.

extending through the levator (or coccygeus) and its fasciae. The incision twice failed over a long period of time to provide adequate drainage of the infection of the infraperitoneal space and to permit healing of the sinus

extending to the lower abdominal wound. These objectives, however, were readily obtained after coccygectomy.

Case 3.—A 22-year-old soldier sustained a bullet wound of the upper outer quadrant of the right buttock on the Italian front, September 24, 1943. A celiotomy was performed within six hours, but only an infraperitoneal pelvic hematoma was found, and the abdomen was closed without colostomy. The immediate postoperative course was moderately stormy and he soon began to drain feces through the wound of entrance. On October 23, 1943, a sigmoid colostomy was performed to divert the fecal stream. The patient continued, however, to drain a moderate amount of pus from the right buttock

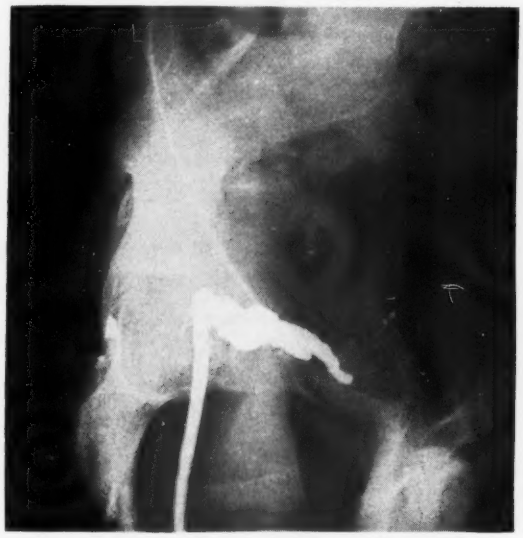

FIG. 13.—Oblique radiograph demonstrating the extension of the lipiodol-filled sinus anteriorly around the rectum on the right toward the symphysis pubis. The tip of the catheter lies in the posterior wound.

and he was returned to the Zone of Interior. On arrival here, the patient was moderately septic and somewhat malnourished. There was loculation of pus in the right buttock near the wound of entrance. The celiotomy wound was well-healed and the sigmoid colostomy was functioning well. Barium enema revealed no abnormality. Proctoscopic examination revealed a deep dimpled granulation three inches above the anal orifice at three o'clock (Fig. 14). The bullet could be felt in the deep tissues of the para-anal region at nine o'clock (Fig. 15).

R. B. C. was 4.2 million per cu. mm.; W. B. C. 7,750 per cu. mm.; hemoglobin 13.5 Gm. per cent; uranalysis was normal; N. P. N. 28 mg. per cent; sugar 99 mg. per cent; plasma protein 7.39 Gm. per cent. Lipiodol injection of the wound of entrance revealed extensive ramifying fistulae in the retrorectal space (Fig. 16). On December 15, 1943, the lower rectum was exposed by coccygectomy, the perforation was closed, the fistulae were widely opened, the bullet removed from the para-anal region, and the entire retrorectal space loosely packed. This wound healed slowly but cleanly. Meanwhile, pus continued to drain from the wound of entrance in the right buttock and finally several spicules of bone appeared. Roentgenologic studies revealed osteomyelitis, with sequestration of the lower aspect of the right sacro-iliac joint. On January 19, 1944, the upper half of the bullet tract was saucerized and sequestrectomy performed. This wound healed slowly but uneventfully until May 26, 1944, when a plastic secondary closure was performed. On July 18, 1944, the posterior wounds having healed, the sigmoid colostomy

was closed. A protective cecostomy was simultaneously established because a nasal deformity precluded passing a Miller-Abbott tube. Both wounds healed uneventfully, and normal bowel habits were restored. The soldier gained in weight and strength and was returned to full duty.

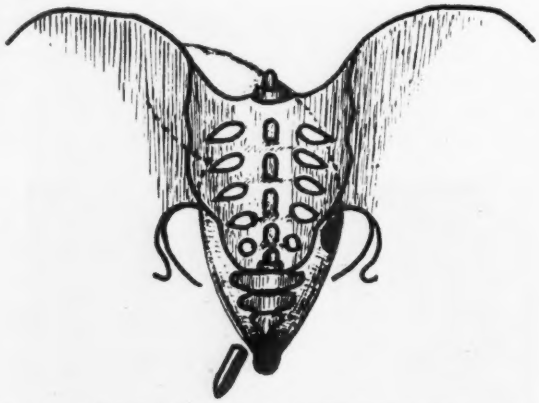

FIG. 14.—Diagram illustrating the approximate location of the perforation of the rectum. (Posterior view)

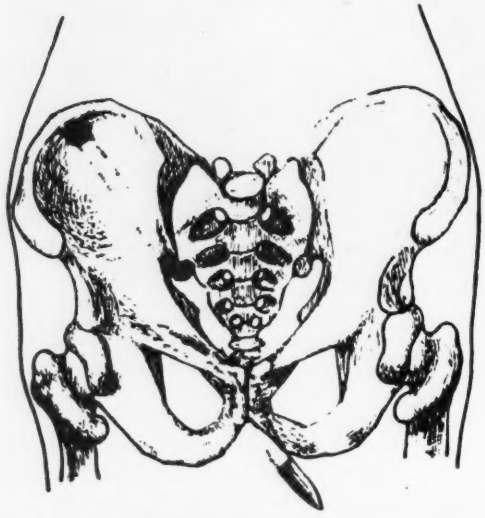

FIG. 15.—Diagram illustrating the approximate course of the bullet. (Anterior view)

COMMENT: This case had a successful outcome, but, likewise, a long and serious morbidity. It is not clear from the records how soon after trauma the perforation of the rectum became manifest by the appearance of fecal drainage from the wound, but it is probable that only a contusion of the rectal wall was present until infection of the bullet tract caused a secondary perforation. This may have saved the patient from death or more serious morbidity since the fecal contents drained into a prepared and partially walled-off fistulous tract. Because the pressure from its direct communication with the bowel was not relieved it soon honeycombed through the little resist-

ing tissues of the infraperitoneal space. Sigmoid colostomy was established one month after the injury, but the damage was already done and the honeycombed labyrinthine fistulae continued to be infected from the communication with bowel. Saucerization of the perirectal space through coccygectomy together with closure of the perforation was necessary to ablate these fistulae. The proximal intramuscular portion of the bullet tract was ignored in our first operation, and it may have been expected to heal were it not for the fact that osteomyelitis of the lower end of the sacro-iliac joint with sequestration, had developed. Once sequestrectomy was performed healing of this portion of the tract developed uneventfully.

FIG. 16

FIG. 17

FIG. 16.—Oblique radiograph after lipiodol-filling of fistula through the wound of entrance and barium-filling of colon, both proximal and distal to colostomy.

FIG. 17.—Lateral radiogram after lipiodol injection of the external fistulous tract in the right buttock revealing its entrance into the rectum.

Case 4.—A 30-year-old officer sustained a through-and-through gunshot wound of both buttocks while on the Italian front on July 16, 1943. He was taken prisoner but subsequently retaken by Allied troops. Meanwhile, a fecal fistula had developed in both wounds of entrance and exit and a sigmoid colostomy was, therefore, established on July 24, 1943. The wounds continued to drain pus and feculent material, and, August 16, 1943, he was returned to the Zone of Interior.

On arrival here, September 22, 1943, his general condition had improved. He was still 26 pounds below his maximal weight. The gunshot wounds had healed and his colostomy was functioning well. Proctoscopic examination failed to reveal any lesion of the lower bowel and barium studies of bowel both proximal and distal to the colostomy were essentially normal. Accordingly, October 4, 1943, the sigmoid colostomy was closed. The immediate postoperative convalescence was essentially normal. On October 19, 1943, the wound in the right buttock reopened and began to drain at first serosanguineous, then purulent material. Lipiodol was injected into its orifice and was found on roentgenologic examination to enter the rectum (Fig. 17). Later, methylene blue, likewise, injected, was observed entering the rectal ampulla in the middle of the

posterior wall 6.5 cm. above the anal orifice but the internal orifice of the fistula was hidden behind a rectal valve. It was decided to treat the fistula conservatively, and by November 22, 1943, the external orifice had healed completely. On January 12, 1944, this wound reopened and discharged feces. Rectal examination now revealed a palpable granuloma in the previously observed location of the internal orifice of the fistula. On January 24, 1944, the fistulous tract was excised, employing a T-shaped incision and exposing the rectum by coccygectomy. The rectal mucosa at the site of perforation was found everted and embedded into an osteoperiosteal scar in the lower segment of the sacrum in such a manner that it could never have healed. After freeing the edges of the defect in the rectum they were inverted by two purse-string sutures, the osseous defect

FIG. 18.—Posteroanterior radiograph showing lipiodol entering the rectum after injection of the external fistulous orifice. The fistula itself appears as a faint line extending to the left. Note fracture of descending ramus of right pelvis.

was curetted and the wound lightly packed and left unsutured. A transverse colostomy was established. Healing was uneventful. Penicillin was administered parenterally. On March 28, 1944, the cleanly granulating posterior wound was revised and secondary suture performed.

On May 25, 1944, the transverse colostomy was closed. Healing again was uneventful. The patient had gained in weight and strength, bowels were functioning normally, and all wounds had been completely healed for several months when the patient was returned to duty on August 12, 1944.

COMMENT: The lessons to be learned from a study of this case are invaluable. Here, again, despite the failure to establish early sigmoid colostomy and adequately drain the infraperitoneal space by coccygectomy, this patient, fortunately, developed merely a fecal fistula rather than a spreading infraperitoneal infection. The reasons for the development of a rapidly spreading infraperitoneal sepsis in some cases and a mere fecal fistula in others is unknown to us. It may be, as already suggested above, that these cases which develop fecal fistula represent late secondary perforations of a contused area of rectum into an already prepared missile tract. However, such an outcome is unpredictable and where there is presumptive evidence of rectal

injury a proximal colostomy should be established immediately as a life-saving procedure. Once a sigmoid colostomy was established, and the intraluminal pressures and gross contamination of functioning bowel removed, the fecal fistula seemed to heal. In the light of subsequent events, it appears that the external orifice and most of the fistulous tract may heal, only to reopen again if the internal orifice at the mucous membrane remains open, and the intraluminal pressure and gross contamination of normally functioning bowel is restored by closure of colostomy. The internal orifice of this fistula would never have healed because the everted edges were embedded in the scarred defect in the sacrum. This scar was not readily discovered because it lay hidden just proximal to one of the rectal valves. This case, likewise, illustrates the unreliability of demonstration of these defects with barium. Above all, it illustrates the importance of closure of the internal orifice of these rectal fistulae, with wide saucerization of the adjoining bowel surface.

Case 5.—A 25-year-old soldier sustained shell fragment wounds of the right buttock and left thigh March 29, 1943, in the North African campaign. He was admitted to a Surgical Hospital where the wound of the right buttock was débrided and found to communicate with the rectum. He was transferred to an Evacuation Hospital where a laceration, 3 cm. in diameter, 7 cm. above the anal orifice, was discovered. On April 2, 1943, a loop-colostomy of the sigmoid was established and opened on April 4, 1943. On April 6, 1943, a large metallic foreign body was removed from the wound of the medial aspect of the upper left thigh. The soldier escaped injury to the neurovascular structures of the left lower extremity. Both wounds healed rather slowly and a chronic fistulous tract developed in the wound of the right buttock communicating with the rectum. The patient was returned to the Zone of Interior. On arrival here, his general condition was fair. He was still some 35 pounds below maximal weight. There was a well-healed, long, lower left rectus abdominal scar through the lower end of which presented the loop-colostomy of the sigmoid. There was a clean granulating wound of the lower aspect of the right buttock about 6 cm. lateral to the anus. Near its center was the external orifice of the fistulous tract. There was a healing wound on the anteromedial aspect of the upper left thigh. Roentgenologic studies of the pelvis revealed a healing fracture of the descending ramus of the right pubis. After cleansing the rectum, proctoscopy revealed the granulating internal orifice of the fistula on the right posterolateral wall of the rectum about 7 cm. above the anal orifice. On May 13, 1943, the fistula was visualized by lipiodol injection (Fig. 18). The lipiodol readily entered the rectal ampulla. On May 30, 1943, the fistula was excised by radial incision overlying its entire extent. The sphincters were spared. The induration margins about the mucous membrane of the internal orifice were trimmed and the fresh margins inverted with fine catgut suture. The wound was then lightly packed open. It healed very cleanly by secondary union. On June 18, 1943, anoscopic examination revealed that the internal orifice was well-healed with a slightly raised margin. On July 8, 1943, the wound of the left thigh was completely healed. The operative wound of the buttock was healed except for a ribbon of clean granulation tissue at the skin level. Accordingly, July 9, 1943, the sigmoid colostomy was closed with delayed closure of extrafascial layers. Bowels functioned spontaneously and normally. Sphincter action was good. All wounds were completely healed by August 20, 1943. The patient regained his weight and was discharged to duty September 27, 1943.

COMMENT: This case is very similar to Case 4, except that the fistulous tract did not close at all, despite the sigmoid colostomy. After demonstrating

the fistulous tract and its internal orifice, the former was excised and the latter properly sutured. This was one of our earlier experiences and because the tract and perforation were low, a lateral approach directly over the fistula and through the levator was employed, without coccygectomy. Suture of the perforation was technically difficult and, in the light of our subsequent experiences, a coccygectomy would have facilitated the repair of the internal fistula and made healing more certain, because of better exposure and wider drainage.

FIG. 19

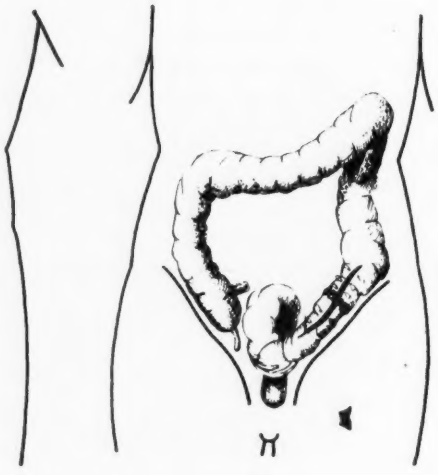

FIG. 20

FIG. 19.—Diagram illustrating the perforations of the rectal wall. (Posterior view)

FIG. 20.—Diagram illustrating the closure of the sigmoid colostomy.

Case 6.—A 36-year-old soldier sustained a mortar shell fragment wound of the right buttock, while in the process of "digging in" during the Sicilian campaign on August 7, 1943, at 1300 hours. He walked to an Aid Station three miles back where the wound was dressed, and then proceeded another ten miles on foot to an Ambulance Station where the wound was redressed. He was then transferred to an Evacuation Hospital, arriving on 1600 hours, August 8, 1943, 27 hours after the injury. At this hospital proctoscopy revealed a perforation of the rectum (Fig. 19), and sigmoid colostomy was established at once without exploratory celiotomy. His convalescence was essentially uneventful. He was transferred to the Zone of Interior. On arrival here, September 25, 1943, the general physical condition was noted to be good. A double-barrel spur colostomy presented through a well-healed left gridiron incision. There was a well-healed scar, 5 cm. long, in the upper medial quadrant of the right buttock. After cleansing the rectum, digital examination revealed a tender pit-like depression at three o'clock and another at eight o'clock, 4 cm. above the anal orifice. These areas were examined on proctoscopy and were seen to be healed wounds. Barium studies of the large bowel, both proximal and distal to the colostomy, revealed no abnormalities. On October 1, 1943, the colostomy was closed by end-to-end anastomosis intraperitoneally. The spur was not reduced in the usual manner because a large artery was readily palpable within its walls. The wound was closed, leaving a Penrose drain to the site of anasto-

mosis (Fig. 20). Convalescence was uneventful. The wound healed *per primam*, and normal bowel function was restored. The patient was discharged to a Reconditioning Center on November 12, 1943.

COMMENT: This case differs from the foregoing cases in that a perforation of the rectum was discovered very shortly after injury and a sigmoid colostomy established. Neither drainage of the infraperitoneal space nor closure of the perforation were performed, and yet the wound perforating the rectum healed uneventfully after early colostomy. This, however, does not justify the omission of these procedures. Fortunately, both the wounds of entrance and exit in the bowel wall were small and clean-cut perforations, without eversion of the mucous membrane into the wound of exit. This cannot be determined at the time of injury, however, without exploration of the bowel wall surgically.

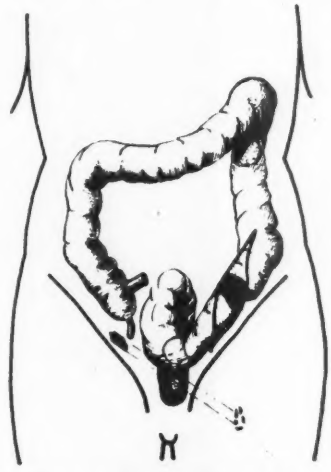

FIG. 21.—Diagram illustrating the course of the missile, the position of the foreign body, and the sigmoid colostomy. (Anterior view)

Case 7.—A 35-year-old soldier sustained a shell fragment wound of the right buttock while lying in a slit trench, on August 7, 1943, in the Sicilian campaign. Several hours later, August 8, 1943, an exploratory celiotomy through a lower right rectus incision was performed at a nearby Evacuation Hospital. No intraperitoneal lesion was found, but there was an extensive infraperitoneal pelvic hematoma. The wound was closed without drainage and without colostomy. On August 13, 1943, he was transferred to another Evacuation Hospital, and a laceration of the rectum was found on proctoscopic examination, accordingly, a sigmoid colostomy was established through a left gridiron incision (Fig. 21). He was returned to the Zone of Interior. On arrival here, September 22, 1943, his general condition was fair except for moderate weight loss. The lower right rectus scar was firmly healed. A single stoma of the sigmoid colostomy presented through a well-healed left gridiron incision. The septum was palpable just below the surface. There was a healed wound, 2 cm. long, in the right buttock, and another, 4 cm. long, in the left. After cleansing the rectum, proctoscopic examination failed to reveal any evidence of any unhealed lesion nor was any scar of a healed lesion recognized. Roentgenograms of the pelvis revealed a metallic foreign body, 1.5 x 1 x 0.7 cm., lying in the pelvis anterior to the upper margin of the sacrum on the right. Another foreign body, 3 mm. in diameter, appeared to lie medial to the right acetabulum. Barium visualization of large bowel proximal and distal to the colostomy failed to reveal any abnormality (Fig. 22).

Accordingly, September 28, 1943, closure of the loop-colostomy was performed under spinal anesthesia, with delayed closure of the extrafascial layers of the abdominal wound. A Penrose drain was placed down to the site of suture. Postoperative convalescence was uneventful. Skin sutures were tied on the fourth postoperative day. The wound was completely healed by October 27, 1943 (Fig. 23). The patient had regained most of his weight but little of his strength. His bowels were functioning normally and spontaneously. On November 12, 1943, he was discharged to a Reconditioning Center.

COMMENT: This is the only case in this series in which evidence of a healed fistula could not be ascertained. This does not, however, discredit the early observation of the presence of a laceration of the rectum, although the position of the lesion was not described. On the contrary, this case illustrates the wisdom of establishing colostomy even on reasonable suspicion of the presence of a perforation of the infraperitoneal rectum. We may go one step further and state that the presence of an infraperitoneal hematoma

FIG. 22.—Anteroposterior radiograph after barium-filling of the rectum. Note the foreign bodies in the pelvis.

from a missile traversing the infraperitoneal space, is presumptive evidence either of laceration of the rectum, contusion of its wall, or infarction from injury to its blood supply, and should be treated by prophylactic sigmoid colostomy. The danger of perforation, with its spreading infection, is thus averted or mitigated at little cost in morbidity. We may go even one step further to state that this procedure should be followed by coccygectomy with drainage of the infraperitoneal space and closure of the perforation of the rectum if one should be found. This additional procedure adds little to the operative shock and may save the patient's life or shorten his convalescence. Drainage of a potentially infected hematoma may prevent actual spreading infection, and even secondary perforation of the rectum.

Case 8.—A 19-year-old soldier sustained multiple shell fragment wounds on the Italian front on July 17, 1944, at 1000 hours. Fragments penetrated the scalp, neck, left forearm, left hemithorax posteriorly, both buttocks, and left leg. The last fragment caused a compound fracture of the left fibula, while one of the wounds of the left buttock perforated the rectum (Fig. 24). On July 18, 1944, several hours after the injuries, at an Evacuation Hospital, all these wounds were extensively débrided and foreign bodies were removed from scalp, neck and leg. A coccygectomy was performed and the infraperitoneal space adequately drained, but it is not known whether the rectal perforation was sutured. A celiotomy was performed under ether anesthesia, and a large retroperitoneal pelvic hematoma but no intraperitoneal injury was found. A sigmoid colostomy was performed. On August 1, 1944, secondary suture of wounds was performed and a skin graft was applied three days later to a wound of the elbow. The patient's convalescence was essentially uneventful. All his wounds healed rapidly and cleanly except the coccygectomy wound. This wound healed slowly and continued to drain pus and mucus. The patient was returned to the Zone of Interior. He arrived here on October 3, 1944.

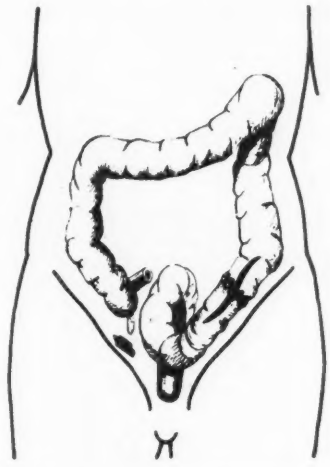

FIG. 23.—Diagram illustrating the closure of sigmoid colostomy. (Anterior view)

On arrival, the patient was somewhat malnourished, since he was still some 40 pounds below his best weight. He was ambulatory and comfortable. His wounds were all healed except for a suspected fistula in the coccygectomy wound already noted. The presence of mucus aroused suspicion of a communication with the rectum. There was a residual paralysis of the left ulnar nerve. The sigmoid colostomy was functioning well. R. B. C., 5.0 million per cu. mm.; W. B. C., 6,500 per cu. mm.; hemoglobin, 15.5 Gm. per cent; N. P. N., 39 mg. per cent.

Proctoscopic examination revealed a small granulating internal orifice of the fecal fistula almost directly posterior, 8.75 cm. above the anal orifice, and its communication with the external orifice in the coccygectomy scar was demonstrated both by lipiodol, and methylene blue injection (Fig. 25). Roentgenograms further revealed residual foreign bodies in the neck and chest.

On October 26, 1944, a resection of the fecal fistula was performed through the original wound. The internal orifice of the fistula was closed with two rows of No. 0000 chromic catgut. The wound was loosely packed, without closure, and has healed uneventfully, but slowly by secondary intention. The patient is now ready for closure of the colostomy to reëstablish the normal channels.

COMMENT: This patient received almost ideal treatment. The surgeon recognized the presence of a perforation of the rectum and established adequate drainage of the infraperitoneal space by partial coccygectomy, then provided a sigmoid colostomy. It seems unlikely that the surgeon sutured the perforation of the rectum, if indeed he found it, since it lay in a position difficult of access on the left lateral wall of the rectum and the remainder of the coccyx had to be removed before it could be reached. This case illustrates, however, that wide saucerization of the infraperitoneal space, with exposure of the rectum, whether or not the perforation is sutured, is adequate

prophylaxis against the death-dealing infraperitoneal sepsis. Failure to suture the perforation of the rectum, however, resulted in this case in the development of a chronic fistula. The presence of such a fistula, if it is short and thick-walled, is not incompatible with a fairly good state of health. Such fistulae once well-established, rarely heal spontaneously and require excision or at least closure of the internal orifice in the bowel wall.

Case 9.—A 30-year-old soldier sustained multiple shell fragment wounds on the Italian front at 1200 hours on May 23, 1944. These fragments penetrated the coccygeal region and the right buttock and perforated the left knee. At 1820 hours, under gas-

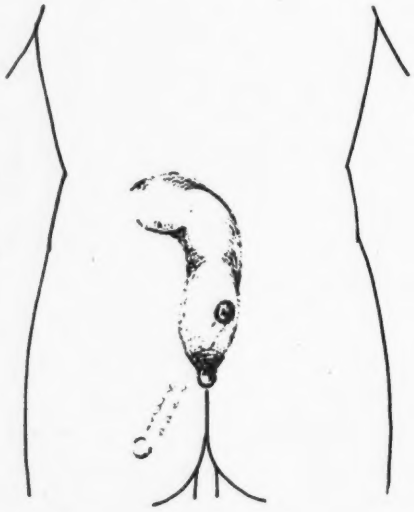

FIG. 24.—Diagram illustrating the perforation of the rectal wall. (Posterior view)

oxygen-ether anesthesia, operation was performed. On abdominal exploration through a lower midline incision, six small perforations of the ileum and one of the bladder were sutured, a sigmoid colostomy and suprapubic cystostomy were established. The abdominal wound was closed about a suprapubic catheter, leaving a rubber tissue drain in the space of Retzius. Coccygectomy was performed, the rectum exposed, the perforation was found and sutured, and the infraperitoneal space loosely packed. The other wounds were débrided and a foreign body removed from the wound of the left knee.

Convalescence was essentially uneventful. The suprapubic catheter was removed on June 12, 1944. A urethral catheter was introduced on June 16, 1944, and removed on June 23, 1944. Since then the bladder has functioned quite normally.

Before the coccygectomy wound had healed, an artery forceps was applied to crush the spur of the sigmoid colostomy but, fortunately, this was rather ineffectual, since little fecal material has passed into the rectum. Meanwhile, the coccygectomy wound failed to heal completely and a sinus developed which drained mucus and pus. The patient was returned to the Zone of Interior.

On arrival here, October 3, 1944, the patient appeared well-nourished, ambulatory and comfortable. His wounds were completely healed except for the coccygectomy wound, in the center of which there was a granulating orifice, 0.5 cm. in diameter, draining a moderate amount of mucopus.

R. B. C., 4.37 million per cu. mm.; W. B. C., 5,700 per cu. mm.; hemoglobin, 12.5

Gm. per cent. Proctoscopic examination revealed a small granulating perforation, the internal orifice of the suspected fecal fistula, 7.5 cm. above the anal orifice, directly posterior. That this was the internal orifice of the fecal fistula whose external orifice was present in the coccygectomy scar, could not be demonstrated either by lipiodol or methylene blue injection, but was finally demonstrated by the passage of a urethral catheter into the lumen of the rectum.

On October 13, 1944, the fistulous tract was excised. The internal orifice was sutured, the investing fascia approximated and the wound lightly packed. Early in the postoperative course, the suture line closing the perforation in the rectal wall, partly reopened. The mucous membrane did not become everted and, with conservative treatment, healing occurred. The wound was allowed to heal by secondary intention. The patient is now ready for closure of the colostomy.

FIG. 25.—Lateral radiograph after lipiodol injection of external fistulous orifice.

COMMENT: This patient received ideal treatment; not only was a sigmoid colostomy established and the infraperitoneal space properly drained, but the perforation of the rectal wall was found and sutured. Unfortunately, this first closure did not hold and the perforation became reëstablished. As in the last case, this merely increased the morbidity without endangering the patient's life. The success of the second closure was threatened. This case illustrates the importance of freeing the mucous membrane about the edges of the defect, trimming away indurated margins and properly inverting the edges with a fine suture. If this is done the break-down of the fascial suture line will probably not jeopardize the closure of the perforation by eversion of the mucous membrane through the reopened fascial defect.

This case, likewise, illustrates the difficulty in demonstrating the entire fistulous tract by employing any one method. In this case, three separate methods were used before success was achieved.

Case 10.—A 32-year-old soldier sustained a mortar shell fragment wound of the left buttock on the Italian front, April 8, 1944, at 1830 hours, while at the latrine in his company area. He tried to walk back to his quarters, but collapsed. He was transported to a nearby Clearing Station, and thence to a Field Hospital where operation was performed a few hours later on April 9, 1944. Under endotracheal ether anesthesia, the wound of the buttock was débrided and perforation of the rectum discovered. Through a midline coccygeal incision, the coccyx was resected, the rectum exposed, the perforation closed and the infraperitoneal space loosely packed. Through a lower left

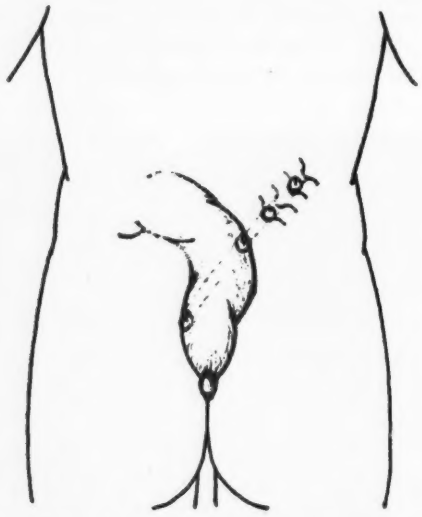

FIG. 26.—Diagram illustrating the course of the missile and perforations of rectum and two loops of small bowel. (Posterior view)

rectus incision, the peritoneal cavity was opened and several perforations of the ileum were discovered and closed (Fig. 26). Then a spur-type of sigmoid colostomy was performed through a left gridiron incision. Sulfadiazine was administered postoperatively. The postoperative course was very satisfactory, and the patient became neither septic nor malnourished. There was some delay in the healing of the transcoccygeal wound due to a sequestrating osteomyelitis of remaining coccyx. The sequestrum was removed, May 9, 1944, and thereafter the wound healed uneventfully. The patient was transferred to the Zone of Interior on July 23, 1944. On admission, the patient's general condition was good. The sigmoid colostomy was functioning well, the wounds were healed, and he had no complaints. Barium studies of the large bowel and proctoscopy failed to reveal an unhealed internal fistulous orifice. R. B. C., 4.4 million per cu. mm.; W. B. C., 8,700 per cu. mm.; hemoglobin, 14.5 Gm. per cent. Uranalysis was negative. N. P. N. was 34. mg. per cent; chlorides, 495 mg. per cent; plasma protein, 7.2 Gm. per cent. After a satisfactory period of observation and recuperation, the sigmoid colostomy was closed extraperitoneally on October 13, 1944. The postoperative convalescence was again uneventful. Rectal evacuations were normal and spontaneous, and he has gained weight. He was transferred to Reconditioning Center on December 8, 1944.

COMMENT: This case illustrates the acme of the current ideal management of infraperitoneal perforation of the rectum. Besides establishing a sigmoid colostomy and saucerizing the infraperitoneal portion of the rectum

the perforation was found and closed. It remained closed and healing occurred quite uneventfully.

All the cases presented above received excellent and early supportive treatment of plasma, blood and chemotherapeutic agents. The difference in their subsequent clinical courses, as we have already indicated, was primarily dependent on the type of surgery and the time of its application. It is probable that many who did not receive early and adequate surgery did not survive to return to the Zone of Interior. The effectiveness of early and adequate surgery in influencing the mortality and morbidity in infraperitoneal rectal wounds is so obvious that it cannot be overemphasized. We have reached the following conclusions as a result of our observations:

CONCLUSIONS

1. Perforation of the infraperitoneal portion of the rectum results in fecal contamination of the cellular tissue of the infraperitoneal space. This space communicates with the retroperitoneal space posteriorly over the sacrum and may, thus, result in fulminating and widespread retroperitoneal sepsis.

2. Even if the perforation cannot be located, but there is a presumptive evidence of its presence or potential development from contusion or infarct of the rectum as judged from the course of the missile and the presence of a large hematoma in the infraperitoneal space, an effective sigmoid colostomy should be established at once.

3. A sigmoid colostomy alone will not prevent infection of the infraperitoneal space, although the infection is likely to be less widespread and fulminating once contact with the normal intraluminal pressure and gross contamination of normally functioning bowel is severed. In addition, the infraperitoneal perirectal space must be saucerized by coccygectomy and loosely packed.

4. Mere saucerization of the perirectal space, while life-saving and prophylactic against spreading retroperitoneal sepsis, is not, however, complete ideal treatment. Unless the perforation is located and closed, a persistent fistula may develop.

The authors wish to acknowledge their appreciation of the contributions made by Major Hazen L. Hauman and Major Joseph M. Miller in the clinical management of the cases presented, and Major A. Bradford Soule in the radiologic studies and photographic reproductions.

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THE SIMULTANEOUS OCCURRENCE OF ACUTE APPENDICITIS AND MALARIA

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SEVERAL COMMUNICATIONS have appeared during the past ten years concerning the frequency with which acute malaria, when associated with abdominal symptoms, may simulate acute surgical disease of the abdomen.[1-7] In two of these papers instances of acute surgical disease of the abdomen were reported as occurring during an acute attack of malaria. Taylor[5] concluded that the differential diagnosis between so-called abdominal malaria and the "acute surgical abdomen" was not particularly difficult, and stated that the necessity of making a differential diagnosis rarely occurred. Our experience, during a period when a large number of patients suffering from malaria were admitted to this Hospital would not substantiate Taylor's complacent attitude.

In the large group of patients suffering from acute malaria we have seen innumerable instances of Castellani's[1] appendicular syndrome, both the acute and chronic forms, cholecystitis syndrome, acute pancreatitis syndrome, and peritonitis syndrome. In certain instances the patients have been seen in consultation with our colleagues on the Medical Service, and in others they have been admitted directly to Surgical Wards because the clinical picture appeared clearly to point to an acute surgical condition.

The clinical picture has, at times, been further confused by the superimposed abdominal symptoms which accompany plasmochin, and, to a much lesser degree, atabrine therapy.

Even the most astute diagnostician will occasionally operate upon a patient for supposed acute appendicitis with malaria, only to find at operation no evidence of an acute surgical abdominal lesion, and, on the other hand, may delay operation until peritonitis makes the diagnosis unmistakable.

We have, during the period when acute malaria was prevalent in this area, operated upon ten patients who simultaneously had acute malaria and acute appendicitis; one who had acute malaria and a perforated duodenal ulcer, and two with acute malaria and spontaneous rupture of the spleen. In three instances at operation for supposed acute appendicitis, the appendix was found not to be inflamed. A brief analysis of the patients with appendicitis is presented in order to point out the difficulties encountered in the differential diagnosis between malaria simulating, or associated with, symptoms of acute appendicitis, and acute appendicitis occurring during a period of acute malaria. These difficulties are further multiplied by the frequency with which patients who are receiving plasmochin develop acute abdominal pain, right-sided tenderness, nausea and vomiting, and even abdominal rigidity during therapy for acute malaria.

Daniel[7] has pointed out that the improvement of the patient's symptoms on antimalarial therapy is a strong indication that malaria is the cause of the patient's abdominal symptoms, while failure to show improvement is an indication that an acute surgical lesion is present. Our experience with the newer forms of antimalarial therapy leads us seriously to question this conclusion, for in many instances we have seen violent abdominal symptoms develop and persist during plasmochin and occasionally during atabrine therapy, making the clinical picture and the differential diagnosis more complex and difficult, rather than less so.

Table I gives the pertinent data in the ten patients with acute malaria proven to have acute appendicitis at operation, and of the three patients operated upon in whom a normal appendix was found.

DISCUSSION.—Of the ten patients proven to have acute appendicitis at operation seven had acute diffuse suppurative appendicitis, or worse, according to the pathologic report and three had acute simple appendicitis. Of the seven patients with malaria and acute diffuse suppurative appendicitis, the white blood cell count varied from 4,100 to 15,000 (mean count 10,175); in the milder cases from 5,600 to 6,350 (mean count 6,680); and in those with a normal appendix 9,330. The count was highest in the suppurative group, but in only three of the seven patients was it above 12,000.

In two, the type was undetermined; three patients were infected with *P. falciparum,* and five with *P. vivax.* In Daniel's series of nine patients with malaria simulating acute abdominal disease seven were infected with *P. vivax* and two with *P. falciparum.* In the three cases where a normal appendix was found two had *P. falciparum* and in one the type was undetermined. It is usually considered that abdominal symptoms are more accentuated in *P. falciparum* infection.

In only four of the seven patients with suppurative appendicitis a chill occurred prior to admission. Pain in the right lower abdominal quadrant was present in all cases, as was tenderness. Five of the seven suppurative cases had rebound tenderness and a similar number rigidity, but these findings were by no means pathognomic of what we found at operation.

Even the temperature at the time of admission was of no significant help, for in at least one patient with perforation of the appendix the temperature was 103° F., and in others the temperature was normal or nearly so, as it frequently is between chills. The findings of parasites in the smear, leukopenia, a chill and a sharp rise in the febrile reaction could by no means be taken as indicative that an acute surgical abdominal lesion was not present. Nausea, and to a lesser extent vomiting are equally frequent in both conditions.

CONCLUSIONS

It should be freely recognized that the differential diagnosis between acute malaria with acute nonoperative abdominal symptoms and acute malaria and an accompanying acute surgical lesion of the abdomen is difficult and,

at times, not possible before operation discloses the true state of affairs. In certain instances with milder symptoms operation may be delayed while intensive antimalarial therapy is being instituted. It is, however, urged that even in these, if the abdominal symptoms and signs do not change for the better, operation be not too long delayed. If this be done the signs of

TABLE I

SYNOPSIS OF DATA ON 13 PATIENTS WITH CONCURRENT MALARIA AND SYMPTOMS OF ACUTE APPENDICITIS

Patient	Chill	R.L.Q. Pain	R.L.Q. Tenderness	Rebound Tenderness	Rigidity	W.B.C.	Nausea	Vomiting	Malaria Smear	Findings at Operation
Case No. 1	+	+	+	+	0	11,100	+	+	Type undetermined	Acute diffuse suppurative
Case No. 2	0	+	+	+	+	4,100	0	0	*P. falciparum*	Acute diffuse suppurative
Case No. 3	+	+	+	0	+	9,100	+	+	*P. falciparum*	Acute diffuse suppurative
Case No. 4	+	+	+	+	+	14,700	0	0	*P. vivax*	Acute diffuse suppurative
Case No. 5	0	+	+	0	0	13,600	+	0	*P. vivax*	Acute diffuse suppurative
Case No. 6	+	+	+	+	+	15,000	+	0	*P. vivax*	Acute diffuse suppurative
Case No. 7	0	+	+	+	+	4,150	0	0	*P. falciparum*	Acute diffuse suppurative
Case No. 8	0	+	+	+	0	7,350	0	0	*P. vivax*	Acute simple
Case No. 9	+	+	+	0	±	5,600	0	0	*P. vivax*	Acute simple
Case No. 10	0	+	+	+	+	7,100	+	0	Type undetermined	Acute simple
Case No. 11	+	+	+	+	+	11,800	0	0	*P. falciparum*	Appendix normal
Case No. 12	0	+	+	0	+	9,600	+	0	Type undetermined	Appendix normal
Case No. 13	+	+	+	0	0	6,700	+	0	*P. falciparum*	Appendix normal

spreading peritonitis will finally force the unwilling clinician to make the diagnosis of an abdominal catastrophe. No reliance can be placed on the symptoms, signs, and type of infection found by smear in attempting to determine with absolute accuracy the differentiation of these two groups of cases.

It is worth while remembering that when a large number of individuals suffering from acute malaria are seen there are apt, also, to be seen individuals who simultaneously are suffering from acute surgical disease of the abdomen.

In the three patients in whom no surgical disease of the appendix was found, in only one was endothelial hyperplasia of the lymph nodes in the terminal mesentery of the small bowel sufficiently extensive to account for the patient's abdominal symptoms. The differential diagnosis is often exceedingly difficult, and at times impossible. Where the physical signs and symptoms strongly suggest an acute surgical abdominal lesion it is safer not to delay operation too long unless prompt improvement of the abdominal symptoms and signs follow antimalarial therapy.

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RIGHT PARADUODENAL HERNIA

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RIGHT PARADUODENAL HERNIA is a rare surgical condition. Only two patients with this condition have been seen at the Lahey Clinic from 1925 to 1944. This incidence corresponds with that stated in the literature. From 1910 to 1939 there were two cases of right paraduodenal hernia treated surgically at the Mayo Clinic.[5] The ratio of right paraduodenal hernia to left paraduodenal hernia is 1 to 3. In 1941, Cogswell and Thomas[3] found a total of 48 cases of right paraduodenal hernia reported in the literature. Operation was performed in 29 of these 48 cases, with recovery in 16 cases. Thus, the mortality has been almost 50 per cent, and probably is higher when we consider that only the cases in which operation was successful are likely to be reported. We are adding two cases in which operation was performed, with recovery, to the total of 16 cases.

Right paraduodenal hernia was defined by Moynihan[7] as having the following characteristics: (1) Almost all of the small intestine is imprisoned in a peritoneal sac behind the ascending and transverse mesocolon and occupies the right half of the abdomen; (2) the opening of the sac is to the left and near the duodenojejunal juncture at the ligament of Treitz; and (3) the superior mesenteric artery or a continuation of it, the ileocolic artery, lies in the anterior portion of the sac. It is for this reason that the surgical correction of this hernia often presents technical difficulties because the vascular supply to the small bowel may be impaired. This hernia is also called internal hernia, retroperitoneal hernia, and intraperitoneal hernia.

Andrews[1] stated that right paraduodenal hernia is the result of malrotation of the ascending colon and cecum. An excellent description with explanatory diagrams of normal and abnormal rotation of the cecum causing right paraduodenal hernia is given by Cogswell and Thomas and will therefore not be repeated.

CASE REPORTS

Case 1.—A white male, aged 47 years, was first seen at the Lahey Clinic on December 6, 1943. The chief complaint was intermittent episodes of diarrhea for 15 years, recurring about once or twice a year. The attacks lasted three days, with associated fever and chills. There was no nausea or vomiting. The stools were light in color and did not contain blood. The episodes of diarrhea increased in frequency until 1940 when he started drinking a quart of buttermilk a day; the periods of diarrhea stopped for two years. In 1942 they reappeared, with a feeling of heaviness in the abdomen. During the past year diarrhea recurred at three week intervals, lasted three days and usually followed a train ride. The diarrhea was so severe that he had

almost continuous stools for hours. The episodes were not related to the ingestion of any special food or to the time of eating. The onset was always sudden and accompanied by fever. He took vitamin B-complex for three months which improved the diarrhea, but chills and fever without pain or abdominal cramps still occurred. There was almost continual gnawing, hunger-like distress in the midepigastrium, unrelieved by eating. No weight loss was admitted. Roentgenograms had not been taken. Four years before coming to the Clinic his stools were examined for parasites, and were negative. The past history and family history were essentially negative.

FIG. 1.—Case 1: Barium enema showing the cecum not filling out well, being concave on the medial side.

On physical examination the patient was moderately obese, weighing 214 pounds. The significant observations were limited to the abdomen which showed tenderness in the right and left lower quadrants.

The patient was admitted to the hospital for study. The gastro-enterologic roentgenograms of the esophagus, stomach, duodenum and small intestine were reported to be normal. The barium enema revealed that the cecum did not fill-out well (Fig. 1), being concave on the medial side. An air contrast enema showed that the entire colon was

distended with air, but the cecum did not distend to a rounded contour on its medial surface. Gastric analyses and roentgenograms of the gallbladder were normal.

Because of the questionable defect in the cecum an exploratory celiotomy was performed under spinal anesthesia by one of us (F. H. L.) on December 17, 1943. A hernia was found which originated in the right paraduodenal fossa through a defect beneath the root of the jejunal mesentery (Fig. 2). Through this defect all the small bowel had herniated and was completely encased in the hernial sac of peritoneum of the

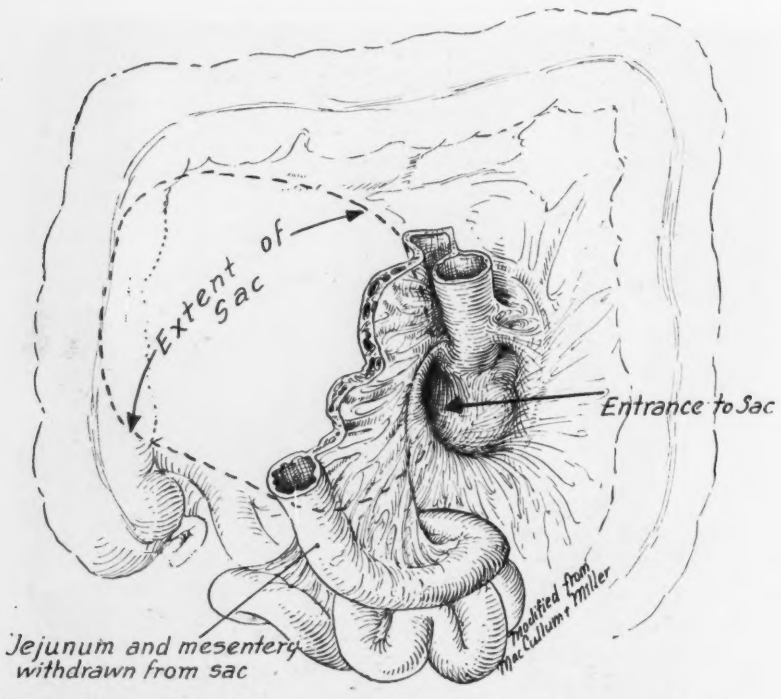

FIG. 2.—Entrance to hernial sac near ligament of Treitz and extent of hernial sac behind mesocolon of ascending colon.

proximal jejunal mesentery and the peritoneum of the ascending and transverse mesocolon (Fig. 3). There was no obstruction of the bowel. There was some angulation at the ileocecal area with some thickening of the terminal ileum as it emerged from the hernial sac to enter the cecum normally. An opening was made in an avascular area of the mesocolon of the ascending colon. Beneath this the hernial sac of the mesentery of the proximal jejunum was incised in an avascular area. The small bowel was freed from it, and the sac traced down to its root at the jejunal fossa where the large defect was found in the mesentery of the jejunum entering from the left. The sac was carefully dissected off the jejunum and the third portion of the duodenum. The neck of the sac was closed with atraumatic chromic catgut, and the redundant portion of the sac was excised (Fig. 4). The intestines were pulled back into the greater peritoneal cavity in their normal position. The peritoneum of the ascending colon was closed with atraumatic sutures, thus peritonealizing the posterior abdominal wall on the right side.

The postoperative course was uneventful, and the patient made an excellent recovery. He was discharged on the 18th postoperative day.

A letter from the patient, dated March 3, 1944, stated that he was "not able thus far to find the slightest trace of the old symptoms."

Case 2.—A 17-year-old white girl was first seen at the Lahey Clinic on April 21, 1944, with the chief complaint of acute attacks of abdominal pain since birth. The attacks of pain occurred in the upper abdomen, and were followed by nausea and vomiting. The vomiting eventually brought relief. The pain was well localized and did not radiate, was severe, but did not require morphine. There was no back pain. Between attacks, digestion and function of the bowel were normal.

FIG. 3.—Case 1: Appearance of the small intestine as though contained in a spherical transparent paper bag.

Physical examination gave essentially negative results. The gastric analysis showed free acid of 45, total acid of 76, and occult blood, 0. On April 25, 1944, a roentgenogram of the esophagus, stomach, and duodenum was considered normal. On May 28, 1944, a second roentgenogram of the duodenum was considered to show malformation of this structure. A third roentgenogram taken on June 14, 1944, was interpreted as showing redundancy of the duodenal loop and absence of the usual ascending loop of duodenum to the duodenojejunal angle (Fig. 5). The jejunum was largely on the right side of the abdomen. The jejunal mucosal pattern was normal. A barium enema (Fig. 6) and roentgenogram of the gallbladder were normal.

Because of the recurring attacks of pain and the abnormal roentgenologic findings,

an exploratory celiotomy was performed on October 31, 1944, by one of us (F. H. L.). A herniation of the proximal portion of the jejunum through the mesentery of the jejunum at the ligament of Treitz was found. Approximately two feet of the jejunum had herniated through the right paraduodenal fossa. There was angulation of the jejunum at the ligament of Treitz. The hernial mass had partially raised the peritoneum of the right upper posterior abdominal wall medial and inferior to the hepatic flexure of the colon. The jejunum was pulled out of the hernial sac. The angulation of jejunum was then straightened by sharp and blunt dissection. The opening of the hernial sac was sutured withfl fine interrupted silk sutures. A small portion of the jejunum was then buttressed against the opening with interrupted silk sutures (Fig. 4).

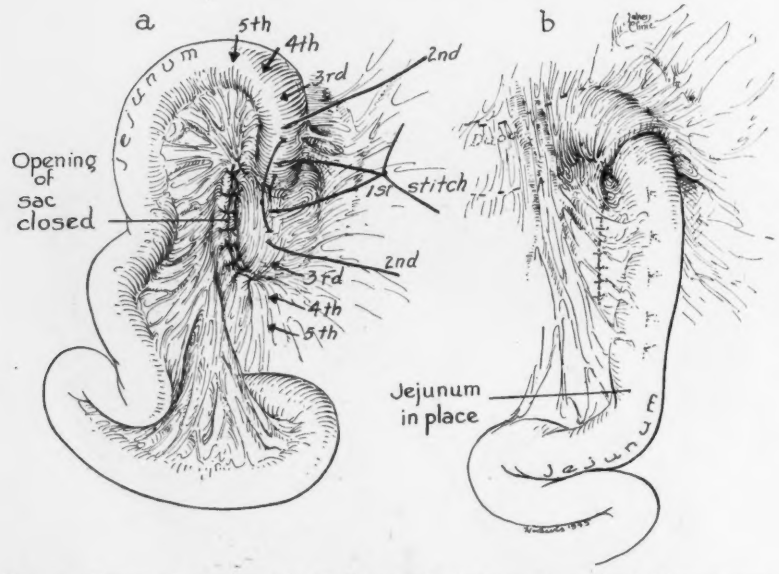

FIG. 4.—Closure of entrance of hernial sac and buttress of proximal jejunum over this closure.

The patient's convalescence was uneventful until the 12th postoperative day, when she had an attack of abdominal pain with considerable vomiting. Wangensteen suction was instituted and intravenous fluids were administered. The following day, November 14, 1944, a partial gastro-intestinal roentgenographic series was made which was reported as follows: Films taken at hourly intervals for six hours showed only a small amount of barium in the loops of small bowel at one hour. At the two-hour examination, barium was scattered through the loops of small bowel, with the head of the meal in the cecum. At six hours there was a large gastric residue, with the duodenal loop also visualized and appearing dilated. The interpretation was marked pylorospasm and dilatation of the duodenal loop.

Following this complication, the postoperative course was without incident, and the patient was discharged four days later, on the 17th postoperative day.

COMMENT.—In reviewing the preoperative roentgenograms (Figs. 3 and 5), it is of particular interest that in Case 1 (Fig. 3) the correct diagnosis might have been made because of the following differential points, as described by Exner[4]: (1) The appearance of the small intestines, as though they were contained in a spherical transparent paper bag from which restricted position

it is usually impossible to disturb the intestinal coils by manual palpation or postural change; (2) the location of the small intestines well above the true pelvis. Normally, the ileum gravitates and lies in the rectovesical pouch. The concavity visible on the medial aspect of the cecum in the preoperative barium enema is now interpreted as being caused by extrinsic pressure on the cecum from the overlying hernial sac (Fig. 1).

FIG. 5.—Case 2: Roentgenogram showing (1) abnormal location of the jejunum on the right side of the abdomen (2) downward continuation of the jejunum from the second portion of the duodenum; and (3) absence of the transverse third and ascending fourth portions of the duodenum traveling to the left across the spine.

In Case 2, the following positive roentgenographic findings diagnostic of right paraduodenal hernia are well illustrated (Fig. 5) and should have led to the suspicion of a right paraduodenal hernia: (1) The abnormal location of the jejunum on the right side of the abdomen; (2) the downward continuation of the jejunum from the second portion of the duodenum; (3) the absence of the transverse third and ascending fourth portions of the duodenum traveling to the left across the spine; and (4) the dilatation of the duodenum as a result of constriction or angulation of the proximal part of the jejunum by the neck of the peritoneal sac, thus causing the symptoms of high intestinal

obstruction, with relief by vomiting. These differential points were emphasized by Case and Upson.[2]

The two cases reported here are very similar to the case reported by McCarty and Present[6] in that there was no evidence of malrotation of the cecum (Figs. 1 and 6), and is explained on the same basis as in their case. It is supposed that one or more loops of small intestine were caught at an

FIG. 6.—Case 2: No evidence can be seen of malrotation of the cecum in this barium enema.

early embryologic stage in a pouch formed by the extraordinarily long mesentery of the proximal jejunum (Fig. 7). As the length and size of the small intestine increased, the hernia increased.

Since right paraduodenal hernia is most commonly found incidental to operation performed for another surgical condition or as the result of an exploration, it is important in every patient with unexplained and persistent abdominal symptoms that the region of the ligament of Treitz be included in general exploration with the possibility of the undiagnosed

existence of such a hernia. Most of these herniae are symptomless for a long time, but if found and reducible, the small intestine should be pulled back into the general abdominal cavity and the aperture left behind, obliterated and buttressed over by the adjacent loop of jejunum to reinforce it (Fig. 4).

The most common presenting symptom of this condition is a varying degree of intestinal obstruction, either partial or complete. Having in mind

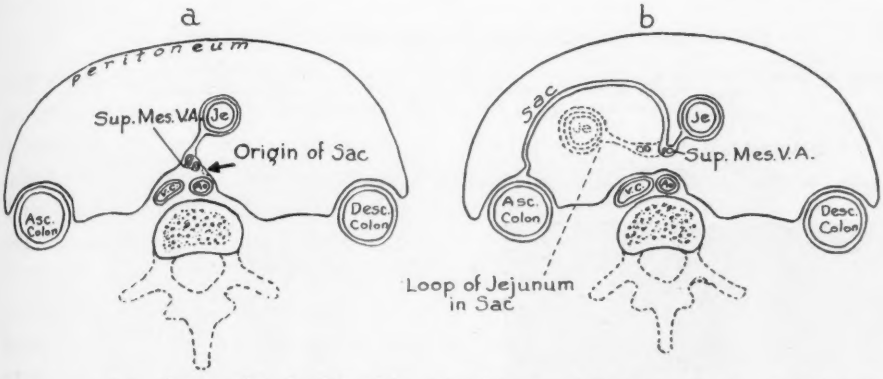

FIG. 7., *a* and *b*.—Cross-section showing origin of hernial sac and its progressive growth with loops of small intestine contained within the growing sac.

the diagnostic roentgenographic features, as described by Exner, and which are present in this series, a preoperative diagnosis, at least in such cases as ours, should be reasonably possible.

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BENIGN CAPILLARY HEMANGIOMA OF DIGITAL FLEXOR TENDON SHEATH*

CASE REPORT

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HEMANGIOMAS of tendon sheaths are sufficiently rare that an additional case seems worth reporting. Harkins, in 1937, collected 24 cases from the literature, including both hemangiomas of the tendon and tendon sheath. He reported 16 cases previously reported by Berman and Milgram, collected eight more from the literature, and added a case of his own. Of the cases listed, only four involved the fingers. They are more common in the forearm and wrist than in the hand. King, in his review of tumors of tendon sheaths, does not mention hemangioma. Mason, in discussing tumors of the hand, mentions angiomata as quite rare, but does not give specific instances. Morton, writing about tumors of tendon sheaths, lists one case of a fibrohemangioma of the tendon sheath of the wrist, but mentions none in the fingers. From his microscopic description and photomicrograph, the tumor was probably similar to that in the present case.

FIG. 1.—Left index finger, fully extended, showing abnormal fullness at the base of the proximal phalanx and overlying the distal head of the second metacarpal.

Case Report.—*Hemangioma of the Flexor Tendon Sheath of Left Index Finger:* H. S., white, male, age 22, was admitted to the Naval Hospital, December 19, 1943, for treatment of a gunshot wound of the left cheek and left thigh which had been incurred on December 13, 1943, during an argument with a civilian. The injury to the cheek was trivial, but the bullet had fractured the left femur in the supracondylar region. Family and past history were noncontributory.

Physical Examination.—This was essentially negative except for: 1. A small crusted wound of the left cheek, which was very superficial. 2. A compound, comminuted fracture of the left femur. 3. A slightly tender swelling at the base of the left index finger on its volar surface.

* The opinions or assertions contained herein are the private ones of the writer, and are not to be construed as official or as reflecting the views of the Navy Department or the Naval Service at large.

Laboratory Data: R. B. C. 3,200,000 Hb. 9.5 Gm., or 66 per cent, W. B. C. 9,800, neutrophiles 77 per cent, lymphocytes 7 per cent, eosinophils 3 per cent, basophils 1 per cent, monocytes 12 per cent. Uranalysis: Negative. Blood Kahn: Negative.

The patient was treated for the fractured femur by the Orthopedic Service, and when essentially well and convalescing from this condition, was transferred to the Plastic Surgical Service, June 2, 1944, for treatment of the painful swelling at the base of the left index finger.

Reëxamination at this time showed the lesion on the cheek to be completely healed, with practically no scar. The femur was solidly united and motion in the knee joint was fairly good and showing steady improvement. The swelling at the base of the left index finger was not appreciably larger than at first examination. This consisted of a soft,

FIG. 2.—Roentgenogram of left hand showing irregularity of radial aspect of the proximal index digit. There is also some condensation of bone along the cortex in this area.

moveable, poorly defined tumor mass lying in the subcutaneous tissues at the volar and radial aspects of the proximal phalanx of the index finger. There was no discoloration of the tissues overlying this mass, and no other vascular or nervous disturbances were noted The mass became most prominent when the finger was completely extended (Fig. 1). It was not tender to palpation, except with heavy pressure, but when the patient attempted to make a tight fist, he was unable to flex the finger completely without pain. The tendons moved freely and did not appear to be adherent to the mass.

Roentgenologic Examination.—Lt. Comdr. Robert K. Arbuckle, M.C., U.S.N.R.: "The left hand shows deformity of the proximal phalanx of the index finger on its lateral aspect. There is erosion of the bone at this point, just beyond the metacarpophalangeal joint, but there is also increased density of the cortex with encroachment of the thickened cortex upon the medullary portion of the bone (Fig. 2). The deformity is chiefly confined to the lateral and volar aspects of the phalanx. The changes appear to be the result of continuous soft-tissue pressure, and there appears to be some swelling of the soft tissues in this region. No clue as to the etiologic factor has been revealed by this study. All of the other bony structures appear normal."

Operation.—June 2, 1944: Under sodium pentothal anesthesia, the left hand was explored through an "S" incision, which began on the radial side of the index finger at the proximal interphalangeal joint and extended proximally to the level of the distal palmar flexion crease. Here it turned ulnarward across the palm, following the crease, and curved proximally with the thenar flexion crease about midway to the wrist. Care

was taken, in deepening the incision, to preserve the digital nerves and vessels which were crossed by the incision. This necessitated careful dissection and was much facilitated by the use of a bloodless field, produced by a pneumatic cuff tourniquet.

Wide exposure was obtained and after reflection of the skin and subcutaneous fat, the palmar fascia was seen to be thinned-out and elevated by a lobulated, yellowish mass in which were seen blotches of purplish tissue. One or two of these areas seemed to form lacunae or cysts, filled with venous blood. Clinically, the tumor resembled a xanthoma of tendon-sheath origin.

FIG. 3.—Diagram of left hand, showing extent of the tumor mass which is represented by the darkly-shaded area.

This tumor apparently arose from the flexor tendon sheath of the index finger, for it was intimately fixed to and mixed with the fibrous tissue of the sheath. Small vessels radiated from the tumor mass to the sheath, and the tumor appeared to be attached to no other structures. It extended dorsally along the radial side of the proximal phalanx and underneath the digital extensor complex. It had caused some flattening and distortion of the underlying bone, but was not adherent to it. The extent of the tumor is shown in the diagram (Fig. 3).

The entire flexor tendon sheath was removed from its beginning in the palm to the midportion of the proximal phalanx, where the tumor ended. Sufficient sheath remained at this point to act as the necessary "pulley" for the flexor tendons. The tendons were found to be smooth and glistening. The remainder of the tumor slipped easily from its bed and no visible remnant of the tumor tissue was left.

The tourniquet was released, hemostasis was secured with fine silk ligatures, and the skin was closed with interrupted fine silk sutures. Pressure dressings were applied.

The wound was dressed seven days later. Healing had occurred per primam, and all sutures were removed. On the tenth postoperative day, motion was begun actively and full motion of the finger was rapidly restored.

On June 20, 1944, he was returned to the Orthopedic Service for completion of his convalescence, and was discharged to duty on July 20, 1944. At the time of discharge, he could make a tight fist without pain and had full range of motion of all joints of the index finger and hand.

Pathologic Examination.—Grossly, the specimen consisted of a plaque of subcutaneous connective tissue, measuring 4 x 2 x 0.5 cm., in which was embedded a semitransparent membrane enclosing a partially cystic structure, which was spongy in consistency (Fig. 4). The encapsulated mass was about six millimeters in diameter, and contained an encapsulated blood clot about three millimeters in diameter. On sectioning, the blood clot was surrounded by spongioblastic tissue which, in turn, was surrounded by a delicate fibrous membrane.

Microscopically, the sections showed a portion of a fibrous capsule which varied in thickness and which extended imperfect trabeculae into a mass of vascular spaces lined by endothelium (Fig. 5). The larger vascular spaces were small, thin-walled veins. About these there were thin capillary-like channels interspersed with strands of endothelial cells. The structure was that of a benign capillary hemangioma of the tendon sheath.

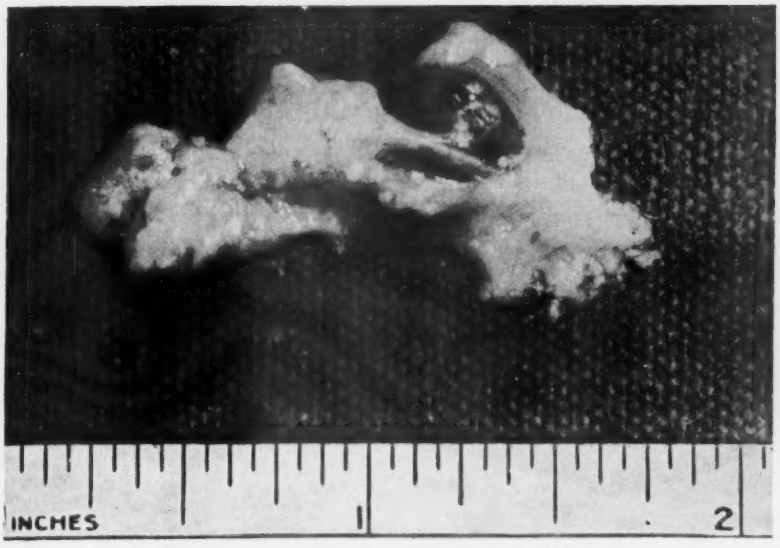

FIG. 4.—Gross appearance of the tumor, showing its lobulated, mottled appearance, with cystic, spongy areas of varying color and density.

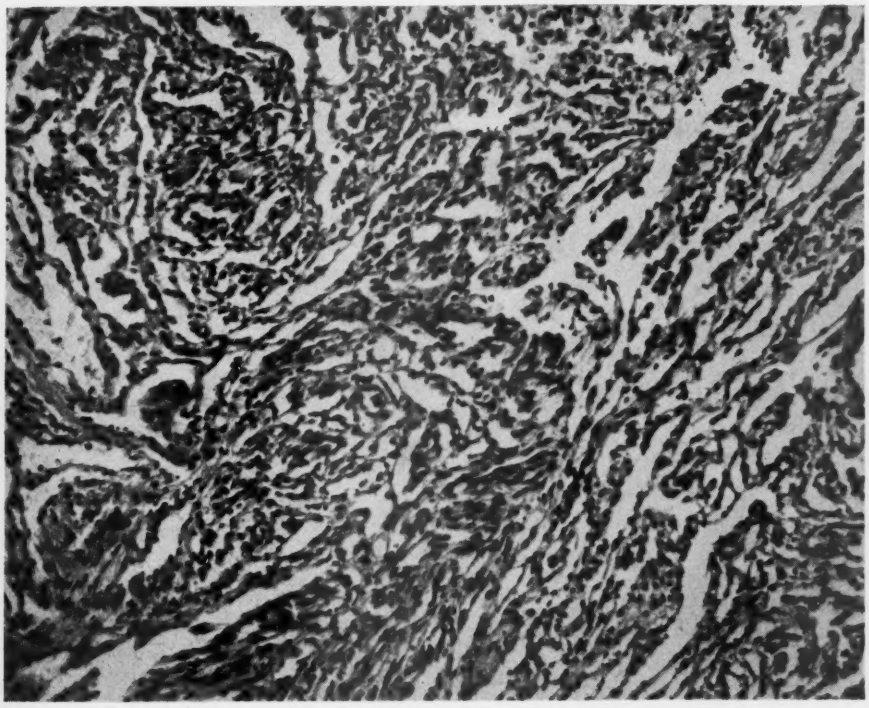

FIG. 5.—Microscopic appearance of tumor, showing ramifying endothelial-lined channels, loose fibrous stroma and strands of endothelial cells, which characterize a benign capillary hemangioma.

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